Utility/Energy Management and Controls System (EMCS) Communication Protocol Requirements

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Acronyms

AC	Air-conditioner
ACGIH	The American Conference of Governmental Industrial Hygienist
AEP	American Electric Power Company
AMR	Automatic meter reading
AMRA	Automatic Meter Reading Association is an international, nonprofit organization that was founded in 1986 in response to concerns about standardization, justification and deployment practices in the implementation of automatic metering technologies
ANSI	American National Standards Institute
ASCII	American National Standard Code for Information Interchange
ASHRAE	American Society for Heating, Refrigeration, and Air-Conditioning Engineers, Inc.
BACnet	ANSI/ASHRAE 135 protocol for Building Automation and Control Networks
BAS	Building automation system. BAS encompasses energy management and control, lighting, fire alarm, access control, and other control functions.
BMS	Building management system. BMS and BAS are often interchangeably used.
CAL	Common Application Language
CAN	Control Automation Network
CASM	Common Application Services Model
CBL	Customer base line. Used in conjunction to real-time pricing in which varying electricity rates are applied to the difference between current consumption and the CBL for the same time period.
CCITT	International Telegraph and Telephone Consultative Committee
CDPD	Cellular digital packet data
CEBus	Electronic Industries Association Consumer Electronic Bus, EIA 600
CENELEC	European Committee for Electrotechnical Standardization

CF	Configuration information
CMIP	Common Management Information Protocol
CMISE	Common Management Information Service Element
COM+	Microsoft Distributed Object Model
ConEd	Consolidated Edison, Inc
COP	Coefficient-of-performance
CORBA	Object Management Group Distributed Object Model – Common Object Request Broker Architecture
CPUC	California Public Utility Commission
CRM	Cost Reflective Messages
DAIS™	Data Access Integration Services
DC	Description
DDB	Dynamic Demand Bidding
DDC	Direct digital control
DDE	Dynamic data exchange. DDE is supported by the Windows operating systems for dynamic updates of data across application programs.
DI	Device identity
DLC	Distribution Line Carrier
DLMS	Distribution Line Messaging Specification
DM	Device model
DNP	Distributed Network Protocol
DNS	Distributed Name Service
DO	Data object
DS	Data set
EDI	Electronic Data Interchange
EHS	European Home System
EIA	Electronic Industry Association, Arlington, VA
EIA	U.S. Energy Information Agency, Washington D.C.
EMCS	Energy management and control system
EMS	Energy Management System
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute

ESCO	Energy service company
ESP	Energy service provider
ETHOS	European Telematics Horizontal Observation Service
ETSI	the European Telecommunications Standards Institute
FDD	Fault detection and diagnostics
Fieldbus/Profibus	Industrial control network
FMH	Federal Meterological Handbook
FMS	Facility management system. An FMS includes an EMCS. FMS may have functionality beyond energy management tasks. FMS, BAS, and EMCS are generally interchangeably used.
GMT	Greenwich Mean Time
GOMSFE	Generic Object Models for Substation & Feeder Equipment
HDLC	High-level Data Link Control
Head-end	Highest control unit in a hierarchical building control network. Typically a head-end is a personal computer connected to zone controllers via common communication bus.
HFC	Hybrid fiber optics and Coax cables
HVAC&R	Heating, Ventilation, Air-conditioning, and Refrigeration
IAI	International Alliance for Interoperability
IAQ	Indoor-air quality
ICAO	International Civial Aviation Organization
IEC TC57	International Electrotechnical Commission Technical Committee 57
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IP	Internat Protocol
ISO	International Organization for Standardization
ITU	International Telecommunication Union
LA	Load aggregator
LAN	Local Area Network
LD	Logical Device
LONMark	Industry-specific, agreed upon guidelines for implementing the LONTalk protocol in various applications. The guidelines promote interoperability in control networks.
LONTalk	Echelon’s Local Operating Node communications protocol

LONWorks	Echelon’s Local Operating Node communications technology. It utilizes nodes (neurons) that communicate with the LONTalk protocol according to the agreed upon guidelines established by the LONMark Interoperability Association.
MAK	Maximale Arbeitsplatz Konzentrationen (Maximal Workplace Concentrations)
MCP	Market clearing price
MDCS	The Metering and Data Communication Standards Working Group was founded as a result of California Public Utility Commission order to develop meter reading standards
METAR	
METAR/SPECI	METAR, French: Aviation Routine Weather Report; SPECI, French: Aviation Selected Special Weather Report
MMS	Manufacturing messaging specification
MX	Measurement
NEMVP	North American Energy Measurement and Verification Protocol
NIOSH	National Institute for Occupational Safety and Health
NOAA	National Oceanic and Atmospheric Administration
OSHA	Occupational Safety and Health Administration
OSI	Open Systems Interconnection
PEEK/POKE	Metaphor for "Basic programming language" memory manipulation instructions
PEL	Permissible Exposure Limits
PF	Power factor. Ratio of real to reactive power
PG&E	Pacific Gas and Electric Company
PID	proportional/integral/derivative
PLC	Power Line Carrier
POTS	Plain old telephone service
PQE	power quality event
PQM	power quality monitoring
PSE&G	Public Service Electric and Gas Company
PSEM	Protocol for Electric Meters, ANSI C12.18, ANSI C12.19
PSTN	Public Switched Telephone Network
PX	Power exchange. Market entity established for the restructured power market. The primary purpose of the PX is to provide an efficient and competitive electric energy auction open on a non-

	discriminatory basis to all suppliers for the purchase of electric power at market prices. PX has been operating in California as of March 31, 1998. Other States are following.
R&D	Research and Development
REL	Recommended Exposure Limits developed by NIOSH
RF	Radio frequency
RTP	Real-time pricing. Electric rates that are subject to changes on a hourly or even more frequent basis. Prices are transmitted in advanced with a specification of prices at a given time. Utilities have experimented with RTP programs in pilot studies.
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition
SCE	Southern California Edison Company
SDG&E	San Diego Gas and Electric Company
SNMP	Internet Engineering Task Force's Simple Network Management Protocol RFC 1156/ RFC1157
SNVT	Standard Network Variable Types
SQL	Structured Query Language
ST	Status input
SWALEC	South Wales Electricity PLC, UK
TLV	Threshold Limit Values published by The American Conference of Governmental Industrial Hygienist (ACGIH)
TOU	Time-of-use electric rates
UCA/CASM	EPRI Utilities Communication Architecture Common Application Services
UCA™	Utility Communications Architecture
UDC	Utility distribution company
URL	Universal Resource Locator
VA	Volt-ampere
VAR	Volt-ampere reactive
WAN	Wide area network
WBAN	Weather Bureau Army and Navy
WHO	World Health Organization

Executive Summary

This document summarizes the findings of the ASHRAE research project 1011-RP, titled "*Utility/Energy Management and Controls System (EMCS) Communication Protocol Requirements*" sponsored by ASHRAE's Technical Committee: Smart Building Systems (TC 4.11).

ASHRAE identified a research need that describes the communication protocol requirements for an automated information exchange between a utility or service provider and the end-user's EMCS. The motivation for this research is similar to the motivation for creating Standard Project Committee 135 (SPC 135)[1] and hence the BACnet standard. Open-systems and interoperability across multi-vendors' hardware provides opportunities for innovation in advanced controls technologies, which ultimately reduces O&M cost and improves the indoor environments. Technological advances can be expected from an open-system communication link between the utility and the end-user's EMCS, particularly, as the electric power retail market becomes more dynamic and end-users are given the choice of selecting services from several energy providers.

This report characterizes the current-state-of-the-art in utility/end-user communication technology. We found that communication technology implementations were predominantly a part of utility/customer pilot projects. The participants were commercial, industrial, as well as residential customers. Real-time pricing transmission and bill information were the main services provided by the communication link between the customer and the utility.

The main focus of this project was centered on the definition of information services and the analysis of communication requirements to enable these services. The following nine information services were defined, and their communication and data requirements were analyzed: (1) revenue meter reading (electricity, gas, water, steam); (2) quality of service monitoring; (3) real-time-pricing transmission; (4) load management service; (5) on-site generation supervisory control; (6) energy efficiency monitoring; (7) weather reporting and forecasting services; (8) indoor-air quality monitoring; and (9) dynamic demand bidding into a power exchange.

The result of the service definition and data requirements analysis is a series of proposed data models that define a set of data and their relation to each other. These data sets are necessary and sufficient for the implementation of any of the proposed services. The guiding principal for the definition of the data model was to propose a data object framework that enables the implementation of services to interoperate across different communication networks and computing platforms. The data models proposed are detailed to provide the specificity necessary for unambiguous implementation of the service. Each data model is described in detail followed by a detailed example of how to apply it. A synopsis of the each service and their associated data models are given below:

[1] SPC 135: BACnet - A Data Communication Protocol for Building Automation and Control Networks

Revenue meter reading. To avoid duplication, relevant meter model standards are used, simplified, and modified where necessary. Significant work has been done for the standardization for revenue meter reading services under ANSI C12.19. The ANSI meter models are very detailed. They were simplified to extract the main functionality and features.

Real-time pricing (RTP) communication. A Tariff data model is proposed to support the communication of pricing information. The Tariff model is designed to accommodate any current electric, gas, water, or cooling and heating service rates, including real-time pricing rate schedules.

Energy efficiency monitoring. Data models for energy efficiency monitoring are defined at a high level of data abstraction. This supports the notion that these services are more likely to be implemented to monitor performance and control at a system level (boiler, chiller, air-handler) rather than at a device component level (e.g., valves, heat exchanger).

Load management and on-site generation monitoring. Control capabilities for load management and on-site power generation are performed at the supervisory level, where load targets are sent to the building automation system. Supervisory control of on-site generation is one of several load management options open to utilities in a distributed generation environment. With the advent of distributed generation concepts using microturbine and fuel cell generators, issues involving the generator's interconnection to the grid and its controllability by the utility are currently being researched at the Institute of Electrical and Electronics Engineers (IEEE) and by interest groups such as the Fuel Cell Council[2].

Weather reporting and weather forecasting. This service utilizes date formats for weather reporting established by the National Oceanic and Atmospheric Administration (NOAA). A microclimate adjustment service was proposed, whereby the subscriber of the service reports local building or campus-specific weather data to the service provider. These location-specific weather information will be used to adjust the regional weather forecast to improve the forecast's accuracy.

Indoor air quality (IAQ) monitoring. The authors recognize the current debate in the IAQ issues. This research is not intended to provide a solution to that debate, rather it will provide a framework that is flexible to support current and future data needs to track indoor-air quality conditions.

Dynamic demand bidding service. This service automates an electric power procurement mechanism, which currently is feasible in deregulated electric power market structures, such as in the State of California. This service represents a future scenario of a potential innovative service that has gained interest in Europe as a means to assist in the overall efficiency improvement of the supply and demand market segments of the electric power system. This service has been proposed with electric power procurement in mind, borrowing from procedures and protocols set by the California Power Exchange for the procurement of day-ahead hourly electric power. The demand bidding service proposed is fundamentally applicable to the natural gas spot market as well. The bidding protocols set by the Gas Industry Standards Board in the US is tailored to natural gas market needs, which differ from those of electric power.

Data modeling was performed using the Common Application Services Model (CASM) developed as part of EPRI's UCA 2 project [UCA 2.0, 1997]. CASM provides a unique

[2] Codes and Standards Working Group, Fuel Cell Council, Washington, D.C. See website: http://www.usfcc.com/wg01.htm

framework for the representation of devices and device characteristics as viewed over communication networks. Data models are provided for constructing translations between the common model of services presented in this report and BACnet, LONtalk, and CEBus. For BACnet, this report proposes extensions to the standard that can represent hierarchical information.

Two recommendations were proposed for ASHRAE to champion the standardization efforts of these services:

1. ASHRAE should use the service definitions and data models proposed in this report as a starting point for developing new BACnet macro objects and services. The result of this effort should be the standardization of data objects and services to enable interoperable building automation system devices to communicate with other service providers.
2. ASHRAE should further develop standardized scenarios for the interoperation of BACnet compliant devices and those of other standards bodies to facilitate their interoperation. This will require close collaboration with other standardization organizations to leverage existing work to the maximum degree possible. It is recommended that ASHRAE utilize the existing work for the following services: (1) revenue meter reading models as established by ANSI C12, (2) on-site generation as established by IEEE SCC21 interconnection of distributed generation, (3) RTP, direct load control as worked on by the Customer Interface working group of UCA and now further developed under the IEEE auspices of SCC 36.

1 Introduction

ASHRAE's leadership in establishing BACnet, the Building Automation and Control networks protocol, provides the heating, ventilation, air conditioning, and refrigeration (HVAC&R) industry with an open-system communication standard that enables multi-vendor hardware to communicate with each other. ASHRAE initiated the standardization efforts several years ago (1987), when only a few scientists and practitioners recognized the great technology innovation opportunities by sharing control information across different manufacturers' hardware. Since then, BACnet has been established as an ANSI standard in the US [ASHRAE 135-1995]. In Europe, BACnet has been selected as a prestandard [CEN ENV 1805-1,2; 1997].

With the recent regulatory and legislative changes transforming the electric power industry from a monopolistic to a deregulated and competitive industry, ASHRAE is again interested in initiating and leading the effort for communication standardization. This time, the information exchange is between the utility and the end-user's EMCS. The motivation for such an endeavor is similar to the motivation for creating SPC 135 and the BACnet standard. Open-systems and interoperability across multi-vendors' hardware provides opportunities for innovation in advanced controls technologies that ultimately reduce O&M cost and improve the comfort and air quality of indoor working and living spaces. Similar technological advances can be expected from an open-system communication link between the utility and the end-user's EMCS, particularly, as the electric power retail market becomes more dynamic and end-users are given the choice of selecting services from several energy providers.

With the current transition of the electric power industry toward a competitive market place, the utilities are searching for new energy services they can offer to their customers. These services are used to distinguish themselves from their competitors. Providing new value added services strengthens the utilities' relationship with their clients, who will no longer be captive customers but rather will be able to choose among several electricity providers. The growing market competition forces the utilities to improve their information systems to reduce cost and to provide the system flexibility to accommodate a constantly changing customer base, as customers switch in and out of services. Utilities have indicated a great desire to know more about their customers in order to serve them better. Customers' load profiles are becoming a valuable asset. To facilitate the utilization of user consumption patterns, the utilities are investigating information technologies to retrieve consumption data directly from the end-users. With the cost of communication technology drastically falling, more direct information exchanges between the utility and the end-user are expected.

In the early 1990s, the Electric Power Research Institute (EPRI) sponsored research to investigate and establish the communication protocols to exchange information among utilities. Several working groups have sprung up as a consequence of this research and are now organized as the (Manufacturing Messaging Specification) MMS Forum, which later became the Utility Communication Architecture (UCA) Forum, and then finally, a standards coordinating committee of the IEEE SCC36. This forum facilitates the specification of internationally accepted, open-systems protocols that lets multi-vendor hardware communicate with each other. The forum defined the "Utility Communications Architecture 2" for a wide range of utility data-exchange applications [UCA 2.0, 1997]. UCA sets out universal requirements and then presents a selection of existing nationally and internationally standardized communications protocols and implementation agreements. This selection approach was taken rather than the development of new protocols. The UCA suite of protocols includes simple "reduced stacks", full 7-layer OSI stacks, and, the Internet suite of protocols.

Working groups were formed to define domain-specific models of device / utility interactions. The "Customer Interface Working Group" focuses on end-user data and has developed a model for load shedding, meter programming, remote service disconnect, and customer outage detection. It has, however, not addressed the linkage to a building EMCS.

ASHRAE is attempting to fill this gap and has identified this research as critical for the development of new communication technologies that will provide new and creative services to the facilities, buildings, and homes, which will improve the utilization energy and create healthy and productive indoor environments.

2 Objectives

The objectives of this project are to:

- inform the HVAC&R community about communication requirements for the integration of utility and building energy management and control systems
- recommend potential enhancements to the existing communication protocol standards for the potential integration of utility control systems with building EMCS
- provide EMCS equipment manufacturers, advanced communication companies, software developers, and building operation personnel with the necessary information to understand the requirements and capabilities of existing and future communication-enabled utility services,
- recommend options for ASHRAE to participate in standardization activities to establish an information exchange protocol between end-users and the utility or service providers.

2.1 Scope of work

To achieve the above objectives, the project is divided into the following four tasks:

- **Characterization of state-of-the-art utility/customer communications technology.** The current state-of-the-art communications technologies that have been or are currently being used for the information exchange applications between the utility and commercial, industrial, and residential end-users are described and characterized. To provide the current knowledge and insight of the current technological development and deployment, a comprehensive literature search was conducted and followed up with numerous telephone conversations to utility and technology providers to solicit detailed information on specific technologies.
- **Definition and description of potential future energy-information services that require utility/customer communications systems.** A set of information services is identified, which the authors deem potentially viable in a competitive energy market. Because there is no criterion for determining the viability of future services in general, the authors propose those services that, based on their technology and market knowledge, would have the potential to provide value to both the utility and the customer. Among the services proposed are: quality of service monitoring, dynamic pricing information service, load management service, weather reporting and forecasting, and dynamic demand bidding services.
- **Development of object-oriented data models to accommodate the services and mapping to existing protocols.** To support the concept of interoperability, data object models were created that describe a representation of pieces of information necessary for the definition of the service. A discussion is presented that addresses the mapping issues of these data objects into protocols such as BACnet, LonTalk, and CEBus.
- **Recommendations of options for ASHRAE to participate in standardization activities to establish protocols for utility/customer communications.** Because of the wide-reaching nature of the services proposed, which involves both the demand and supply side, there are numerous standards organizations that may have overlapping domain responsibilities. The report describes domain responsibilities of the relevant standards organizations including the: (1) American National Standards Institute (ANSI), (2) Institute of Electrical and Electronic Engineers (IEEE), (3) International Electrotechnical Commission (IEC), and (4) non-standards development organizations. The report will conclude with recommendations for ASHRAE to proceed in playing an active role in standardization activities for utility/customer communications applications.

3 Characterization of State-of-the-Art Utility/Customer Communication

3.1 Introduction

Utilities and telecom companies have been experimenting with energy and non-energy information services for several years. Strategic partnerships and joint ventures have been created to bring to bear the synergism necessary for the systems development of new products and services. Most of the experimentation has been performed in small-scale pilot programs with a relatively small number of participants. The majority of the technology implementations are centered around services such as automatic meter reading, outage detection, and real-time-pricing (RTP) transmission. Only recently, spurred by the restructuring efforts in the electric power industry and the Telecommunication Act of 1996 [Telecom 1996], the industry has made bolder steps in marketing and implementation of information services, however, with little or no energy content. Most of the services offered are Internet and cable TV services. Given that a communication infrastructure is being developed by means of these applications, the same communication device transmitting entertainment information can be used to transmit energy information service in future applications. With the exception of automatic meter reading (AMR) services, the energy communication field has not experienced the long expected growth, showing no significant growth in this area over the last ten years. However, the growth in AMR services has been driven by restructuring electricity markets, which require flexible and hourly electric consumption meter reading capabilities. According to the Automatic Meter Reading Association, the total number of AMR units installed in North America increased by 4.3 million units in 1998, an increase of 30% from 1997 [AMRA, 1999]. Most of the non-AMR services have involved real-time pricing transmission and direct load management applications. Those applications are still being tested in pilot projects to demonstrate new technology.

The main focus has remained on automatic meter reading, power quality monitoring, outage detection, and direct billing information access. Real-time pricing transmission and its integration into building automation systems (BAS) has been automated in only a few pilot programs. Direct load management applications were predominant in residential homes, where appliances such as the washer and dryer were scheduled to operate during off-peak periods. Condenser units of residential air-conditioners and water heaters were also targeted by utilities as an effective direct load management strategy. On-site power generation from emergency generators has only recently been offered by technology companies and generator manufacturers. With appropriate switch-gear and communication technology, the utility or an energy service company (ESCO) can dispatch emergency generators and monitor the operation of the systems. Energy monitoring, alarm response, and diagnostics have traditionally been in the domain of ESCO subsidiaries of the large building controls companies. Recently, web-based applications have emerged that provide gateway capabilities to interface commonly used EMCS. These systems are bundled with other asset management services to provide full solutions to property management companies and ESCOs for load management, energy efficiency monitoring, alarm response, and diagnostics, as well as providing facility management functions such as asset inventory, facility maintenance scheduling and automated processing of work orders and procurement.

3.2 Commercial/Industrial Versus Residential Products and Services

Providers of energy information services offer commercial and industrial customers different products than those offered to residential customers. The service and functionality provided by the product may be similar or even identical among the customer groups; however, the enabling technologies and systems to provide these services are generally different. For commercial/industrial customers, the incoming information from the service provider is processed by the head-end of the EMCS, which, in most cases, is a PC with a Microsoft Windows operating system and large processing and data storage capacities. In a residential application, the processing and data storage capabilities are generally limited. The device receiving messages from the service provider is typically a microprocessor unit embedded in an intelligent thermostat or located in a small box (residential gateway) outside the home and connected to a low cost home local area network (LAN). One example that illustrates the similarity of the services, but utilizing different technology, is the transmission of RTP information. In commercial/industrial applications, the RTP messages generally consist of 24 data items specifying time and price, whereas in the residential pilot programs, the use of price tiers (low, medium, high) that were only transmitted when a change occurred were more common. The latter implementation of varying electric rates clearly requires less data handling and computational processing capability. However, the functionality of the service is similar, in that they attempt to defer high energy intensive processes to low priced time periods.

3.3 Communication Technology and Information Services for Commercial and Industrial Customers

3.3.1 Introduction

The following sections characterize and describe major representative information service applications and enabling technologies. By no means does the technology characterization claim to describe all information technologies currently offered by utilities and ESCOs. This field is very dynamic with rapid technology developments and special applications serving niche markets. Rather than being all encompassing, this characterization describes key applications and technologies found in the literature that are unique, novel or have been implemented in large-scale technology demonstration projects.

3.3.2 RTP Transmission Enabling Technology

There are two products commercially available for the automated transmission and processing of RTP messages. They are offered by Honeywell and Enerlink, a business unit of Science Applications International Corporation[3].

Honeywell provides an entire software suite called Real Time Pricing™, (RTP™) as an accessory for Honeywell's building management system (BMS). RTP™ is a turn-key solution for automated operation, which completely automates the operation of facilities in response to varying electricity rates. It includes communications programs for both the utility and the

[3] Science Applications International Corporation (SAIC) acquired the EnerLink business unit from Southern Company Energy Solutions, a subsidiary of Southern Company on January 26, 1999.

customer, and an RTP control module that processes the RTP information and device strategies to reduce electricity cost. The Utility Master Station™ is a software tool for the utility to send RTP rates and other information to the customer's BMS via telephone lines using a modem. The Utility Master Station™ communicates directly with the Customer Communication Gateway™ on the customer's site. The RTP rate information is stored in an ACCESS database from which the RTP™ control module accesses the rates and applies algorithms and control strategies to limit loads and/or reschedule and shift loads to minimize cost. The controls strategies are invoked by price triggers. If a RTP rate is above a certain threshold value, predefined loads are turned off, or variable loads determined by temperature set-points or flow rates can be modulated. Additional operating constraints can be imposed before loads are turn off or deferred. For instance, minimum ventilation rates could be checked if available via the BMS to maintain indoor air quality (IAQ) standards. Lights could be dimmed if no occupancy is sensed in certain zones. The controller provides a high degree of flexibility to define conditions that must be met before RTP control strategies are imposed. Because of the transparency of all of the control points controlled in the BMS to the RTP™ controller, the user has great flexibility to define operating constraints and conditions before RTP control actions are executed. The communication between the Utility Master Station™ and the Customer Communication Gateway™ is compliant with the Utility Communication Architecture (UCA version 1), a communication standardization development supported by the Electric Power Research Institute. Honeywell employed a reduced communication layer stack using UCA 1.0. Version 1 has been superceded by version 2 to specify the implementation of interoperable communication technology. [UCA 2.0, 1997]

Extensive detail on the implementation of the RTP™ controller and the integration into the BMS can be found in Honeywell's patent titled "Real-Time Pricing Control System and Methods Regarding Same" [WIPO, 1997].

Honeywell showcased this technology at the Marriott Marquis Hotel in New York City in 1995 [ELECTRICAL WORLD 1996], [EPRI, 1997a], [Gabel et al., 1998]. Sophisticated load shedding measures were applied to reduce the peak demand and electric energy consumption during high price periods. The control measures included dimming the lighting, temperature setbacks, pre-cooling during early morning hours and shifting of electrical equipment operation to low price hours.

The World Financial Center in New York City is another facility equipped with the Honeywell RTP technology. This facility has a thermal energy storage that is controlled using an optimization approach, which determines an optimal charge and discharge protocol to minimize the cost of electricity. Other applications of the Honeywell technology are the Emory University Hospital in Atlanta, the Atlanta International Airport, and buildings at the McCormick Company and at AT&T, both in Hunt Valley, Maryland.

Enerlink, , a business unit of Science Applications International Corporation., offers an entire suite of software products to energy suppliers and energy users for various aspects of load monitoring, rate analysis and RTP rate dissemination, flexible billing, and other administrative functions. RTP Mail™ is the communication component of the software product line. The delivery of the RTP rates is customized and depends on the particular RTP tariff and the utility delivery preference. The utility may chose to provide a web-based solution, where the customer retrieves the RTP price information from a secured web site or, alternatively, the utility may post the RTP rates in a customer's electronic mailbox. Via the Enerlink Load Monitor, the customer can access the facility's electric meter and retrieve the most current electric consumption data.

With the current rate and consumption data, the customer can determine the approximate real-time cost of electricity. For those RTP tariffs that are designed to ensure revenue neutrality, the customer needs to know its customer base line (CBL) to estimate the cost of the electric service. Under revenue neutrality clauses, the varying RTP component is applied to the difference of the actual load to the CBL. For actual loads exceeding the CBL, the customer is charged the RTP rate; for loads below the CBL, the customer receives a credit. Enerlink provides the CBL Manager™ to the utility to establish the customer specific CBL, which is defined for an entire year. The CBL is provided to the customer once and updated every year.

Enerlink recognized quickly that it had to create strategic partnerships with the buildings and process controls industry to market the product effectively. Enerlink offers connectivity solutions to exchange RTP data with Honeywell's energy management system, as well as Hewlett Packard's Vantera real-time measuring and data management system.. The interface to the Honeywell BMS is customized for each integration application. The Enerlink system defines a set of rules and conditions that, when met, signals the Honeywell BMS to read the RTP rate. The RTP rates are then read into the BMS database for further processing by Honeywell's RTP controller. [Enerlink, 1999]. Enerlink also partners with AT&T to establish customers' mailboxes, AT&T's network for the transmission of RTP. [Enerlink 1997a,b,c]. Enerlink claims 52 major U.S. utility companies are using and distributing Enerlink products. It is unclear, how many RTP applications are currently being used. Most likely, not all utility companies are employing Enerlink's RTP tool.

3.3.3 Energy Efficiency Monitoring, Alarm Notification, and Load Management Services

Remote energy efficiency monitoring, alarm notification, and load management have been the domain of those ESCOs who are subsidiaries of buildings control vendors. Full service solutions can be offered by ESCOs providing hardware and systems maintenance and energy management services. By having the technological know-how of accessing their parent companies' control technology, these ESCO have enjoyed a strategic advantage and, thus, have grown significantly. Johnson Controls, Inc., for instance, has over 1 billion square feet of client space under management [Johnson Controls, 1998]. Typically, telephone modems are used to request system status information and consumption data. The call is generally initiated by the central control center. In cases of alarm notifications, the remote station initiates the call to the central control center.

With the ubiquitous access to Internet services, new players have emerged offering web-based application programs for energy monitoring, load management, and diagnostics services. These players are relatively small software companies that are aligned with utilities or ESCOs. The technological approach of web-based tools is similar to that of an intranet and Internet-based corporate information system. Given the communication infrastructure of corporate computer networks, the same infrastructure can be used to send and retrieve energy related data and real-time BAS control information. These web-based monitoring and control systems are being primarily marketed to ESCOs with large national accounts, universities with many campus buildings and facilities, and large corporations that perform their own energy and asset management.

Silicon Energy, for instance, is a small company that offers enterprise-wide energy management and control products and services using the TCP/IP protocol and a web-based interface. The key to this product is to leverage the information that resides on disparate BAS systems for near real-time consumption analysis. The product provides two-way communication and connectivity to commonly used building control networks [Patterson, 1999], [Lundin, 1999], [Silicon Energy, 1999]. This enables the user to "drill-down" on particular system components to determine the root cause of problems. The full two-way communication allows the user to reset set-point parameters on-line on the BAS. The system includes a sophisticated alarm notification system that enables the operator to determine likely causes for a system problem before service staff are dispatched to the site. It has prioritization features for system alarm notification to handle potentially hundreds of alarms that may arrive from numerous buildings and facilities at the same time. The central database architecture of this product allows sophisticated queries on the load and consumption data of all of the subscribing customers. For instance, energy efficiency indices such as electric energy per floor area (kWh/ft^2) over a specific time period (e.g., day, week, and year) can be determined for each customer and sorted in increasing or decreasing order to establish a ranking among all customers.

3.4 Communication Projects for Residential Customers

3.4.1 Transtext Project, American Electric Power

American Electric Power Company (AEP), a Midwest utility, is currently conducting a small-scale pilot study with a communication technology called TranstexT. Although TranstexT has had a long history from the mid-1980s, this section discusses its current applications and structure.

AEP's TranstexT technology is currently in the second phase of a pilot program. The program was initiated in 1993 and entered its second phase in 1996 with 250 homes.

AEP offered 250 residential homes TranstexT as a hybrid two-way communication and home automation technology that enables participating customers to develop electric load management strategies according to price signals sent from AEP. TranstexT encompasses two communication devices (transceiver and dial-out modem) to communicate with the utility, and a home automation network based on the CEBus™ standard protocol. A central control unit provides programmability for load management strategies and data collection. Communication from the utility to the TranstexT homes is established by AEP's 800 MHz radio transmitter. The radio transmitter has a high output of 100 W reaching all participating homes. The return communication from the homes to AEP is established via telephone lines and a dial-out modem in each home unit.

The home automation system uses the CEBus protocol over the power line in the home and is controlled by a central control unit. The central control unit is connected to the dial-out modem for downloading zone temperatures, thermostat set-points, and electric energy consumption (kWh) for the entire home and for selected electrical appliances (such as washer, dryer, dishwasher, electric water heater, and electrical heat pump). The dial-out modem is programmed to a set schedule or at request by the utility over radio frequency transmission.

The pilot project was approved by State Public Utility Commissions in Ohio, Indiana, Illinois, and Kentucky. The rate structure for the pilot program is based on a four-tier tariff system, with three of the four tariffs being scheduled and fixed in advance. The fourth tier is in effect under critically low reserve margin conditions when the utility requires load relief from the demand

sectors. Under the critical condition, AEP broadcasts a '*change of tier*' message, which overrides the current tier that is in effect and shuts off designated electric appliances to shed loads.
The wide area broadcasting communication is rather limited and encompasses only the following three messages:

- Change of tier to 'critical'
- Test call for dial-out modem communication testing
- Call out and transfer consumption data.

These three messages are sufficient to induce a load shedding measure applied to the entire universe of participating homes, but it is not capable of invoking varying degrees of load shedding based on the severity of the critical supply condition. Furthermore, the communication broadcast is not scalable to a diverse group of customers that would include commercial or even industrial customers with widely ranging load requirements and load management opportunities.

3.4.2 Comverge Customer Connection

Comverge Customer Connection utilizes a residential gateway technology that connects the home metering and automation system with a host computer at the utilities' facilities over one or more wide area networks (WAN). The technology is a platform by which distributed applications can be deployed requiring both components close to the customer site (i.e., in the gateway) and at the utility or the energy service provider host. With initial research and development (R&D) under the Lucent Technologies name, Comverge was spun off from Lucent Technologies Utility Solutions to further develop and market the technology. The initial implementation of this technology was piloted with the Public Service Electric & Gas Company (PSE&G) of New Jersey; 1000 homes were instrumented with the gateway technology. This pilot study was unique in that PSE&G provided real-time-pricing information to the residential customer to encourage load management activities as well as performed AMR. Detailed information on the PSE&G pilot study can be found in [Goldman, C., 1996].
Comverge's Customer Connection provides real-time two-way communication between the utility or energy provider and the residential or commercial customer site. It is entirely based on open communication standards and, thus, compatible with current network infrastructures. The gateway provides connectivity to the customer's LAN, which uses the CEBus protocol [EIA/IS 60, 1992]. The CEBus LAN can be established over the power lines, twisted pair, or radio frequency transceivers. The gateway communicates with the utilities' Data and Communication Management Subsystem over the WAN using the Utility Communications Architecture (UCA) protocol. The WAN can be established using hybrid fiber optics and coax cables (HFC), cellular digital packet data (CDPD), or plain old telephone service (POTS) lines. The gateway technology has sufficient processing power to load third party applications to perform various control measures. The residential gateway was designed to facilitate the following services [Comverge, 1998]:

- automated meter reading
- direct load management by the utilities
- customer controlled load management
- real-time pricing messages
- remote outage detection
- remote service connect and disconnect
- tamper detection.

Comverge’s new technology is currently being implemented in a pilot program with the Volunteer Electric Cooperative in Tennessee with 22 participating homes. The final installation is planned to be completed in 1999. The emphasis of this pilot program is to test load management strategies by supplying real-time-pricing information to the customers. The main target of the load management is to optimally use the electrical water heater so the cost of electricity is minimized. The Cooperative will gain knowledge of the price responsiveness of the participating customers.

Consolidated Edison, Inc. (ConEd) in New York City is also experimenting with Comverge’s technology in ConEd’s Learning Center. The Learning Center is a 100,000 ft^2 commercial building. ConEd’s interest in the technology is to gain experience in accessing metered electricity data via the Internet.

3.4.3 European ETHOS Program

Under the European Commission funded European Telematics Horizontal Observatory Service (ETHOS) umbrella, the load management system CELECTR is being tested in large field trials. It involves 763 homes in four European countries. (UK - 285, Denmark - 100, France - 270, Italy - 108). CELECTR is a UK-developed load controller designed for electric space heaters with thermal storage to optimize the charging and discharging cycles under cost minimization principles. It requires a daily weather forecast to perform a load prediction for the next day. The electric rate for all homes is a time-of-use rate. CELECTR has been extended in its functionality to control the operation of water heaters, washers, and dryers. The weather forecast is transmitted over a long wave radio transmitter and received at a residential gateway that communicates to CELECTR via the European Home System (EHS) protocol. The objective of this project is to field test the effectiveness of the load control and to gain experience with the EHS communication protocol as a European standard for home automation. The project was started in 1995 and recently ended in 1998. The Commission of European Communities has committed major financial resources toward the establishment of home automation standards, including gateway technologies.

South Wales Electricity PLC (SWALEC), one of the larger UK utility participants of the project, cites the following objectives for the ETHOS project [SWALEC, 1998]:

1. To enable the distribution company to reduce peak demands on its electricity distribution network and to avoid the cost of reinforcement.
2. To enable the supply business to reduce its wholesale electricity purchase costs.
3. To enable customers to enjoy improved levels of comfort.
4. To enable customers to reduce their electricity purchase costs.
5. To remotely read electricity meters.
6. To research customer attitudes to the new technology, i.e., home automation and multimedia services.
7. To provide the utility with a competitive advantage in the new deregulated energy supply market.

The utility established one- and two-way communication links to the customers. Two-way communications were implemented via the public switched telephone network (PSTN) and distribution line carrier (DLC). One-way communications were implemented from the utility to customer using broadcast radio. Within the customer's building, the data received are distributed to energy controllers and appliances using EHS via power line carrier (PLC) or dedicated twisted pair cabling. The utility company in the SWALEC trial cases transmitted the following information:

1. Tariff information, ranging from a simple four tier time-of-use tariff to a complex time of day/day of week/month of year tariff.
2. A complex set of cost reflective messages (CRMs) that reflect, through 48 half-hour periods, the utility's cost of purchasing energy from generators at the power pool.
3. Weather forecast, for use by the heating system.
4. Time, to keep the energy controls synchronized with our cost/tariff data.

With the PSTN or DLC connection to the customer's gateway, the utility could read the electrical meter. The customer received from the gateway load management or pricing information to perform load management strategies determined by the energy controller. The controller communicated with space heaters, water heaters, dishwashers, washing machines, and clothes dryers. The weather forecast was transmitted via one-way radio transmission.

During trials lasting up to 16 months, SWALEC reported positive and very encouraging results, both from the utility's and customer's point of view. The utility reduced peak demand and, thus, deferred distribution-upgrade cost, while at the same time the customer reduced the overall electricity bill.

3.5 Trends in Utility/Customer Communications

While research and technology development activities in the utility/customer communications area do exist, the progress has been rather slow, compared to other fields of telecommunication and computer networking applications. Major contributing factors for the inertia of technological development are the risks associated with the investment in the communication infrastructure to reach each customers' house or facility. It is the 'last mile' in the utility/customer communication network that is the most expensive. Utilities, therefore, are very cautious in their commitment to large capital investments for new services, which the customers may or may not purchase. In addition, restructuring efforts in the electric power industry leaves the regulated utilities uncertain as to what business they will be allowed to do in the future. However, once the 'last mile' in the communication network is in place and sufficient bandwidth is provided, many new energy and non-energy-related services can be deployed.

Pilot studies exploring the interest of energy and non-energy information services among participating customers did not clearly indicate that the customers are willing to pay for the new service. A recent industry survey revealed a cautious interest in information services offered by the utility. Only 25% to 45% of the more than 5000 commercial and industrial customers surveyed indicated an interest in information services, such as aggregated utility billing, central energy control, central energy monitoring, and fire and security alarm monitoring [EPRI, 1998a].

Given the risks associated with the investment of the communication infrastructure that reaches every home, commercial building, and industrial site, the industry is likely to move forward very cautiously. Improvements are expected to be incremental with the formation of partnerships to diversify the risks among several partners. There may not be a single 'killer application' in the utility/customer communication that will generate a large infusion of venture capital, which could upgrade the communication infrastructure. It is more likely that infrastructure improvements are a consequence of small steps of incremental progress.

The Electric Power Research Institute, in its recent *Electricity Technology Roadmap* clearly identified utility/customer communication as a vital and increasingly more important component of new revenue streams for the utility companies of the future. As microprocessors become embedded in every appliance and as this distributed intelligence becomes increasingly linked to intelligent controllers that have direct access to large networks, such as the Internet, the country's electricity control networks and information systems will converge to one large integrated network [EPRI, 1998b]. EPRI foresees that "in smart homes of the not-too-distant future, controllers could automatically search the Internet for access to the lowest-cost power or seek power with other valued attributes, such as green power or high-reliability power for critical applications." While the scenario for the residential customer may appear to be far out into the future, the earliest adopters will most likely be the commercial and industrial customers in deregulated energy markets. To date, the regulatory framework for the dynamic procurement of electric power already exists. California, for instance, offers end-users the option to bid their load directly into the California Power Exchange for the purchase of wholesale electric power at hourly spot-market prices (demand bidding). To realize the future scenario above, would require the integration of the facility management system with the bidding communication technology. With an integration of the facility management, company accounting, and the bidding system, bid scenarios could be generated automatically based on load forecasts, the flexibility to manage electric power demands, and the assessment of the economic value of consuming electric energy at each hour of the day.

4 Potential New Customer Communications Services

This section presents potential new services for one- and two-way communication between utility or energy service providers and customers.

4.1 Conventions Used In This Section

Conventions used in this section to present the nature and implementation requirements of the new services are described in the following sections.

4.1.1 Service Descriptions

Each service is presented by defining the following parts:

Service objective	<definition>
System objective	<definition>
Nature of data transfer	<definition>
High level data object model	<definition>
Time sequence diagram	<definition>
Bandwidth requirements	<definition>
Data security issues	<definition>

4.1.2 Summarized Data Models

The data models presented in this section are aggregated versions of the detailed models presented in Section 6. They are summarized using the following format:
First a tree diagram of the model is presented:

```
XXX
|__component1
|__component2
```

Figure 4-1: Tree Diagram for the XXX Object Model

Then, the components of the model are summarized:

<u>component1</u>
Description of component1

4.1.3 Time Sequence Diagrams

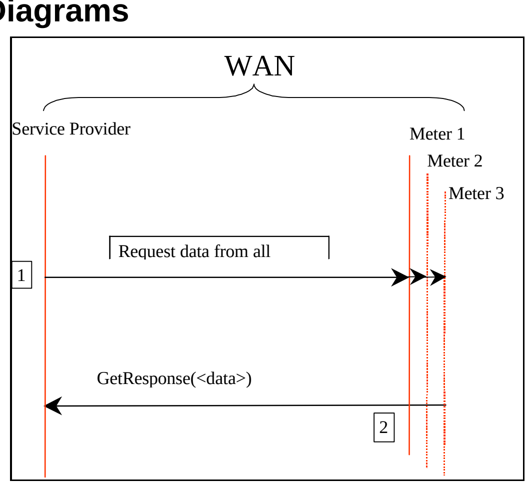

Figure 4-2:Time Sequence Diagram for Service XXX

The time sequence diagram illustrates events of messages and the sequence in which they are being transmitted between or among a set of participants. According to the convention used in this report, the service provider will be on the left-hand side and the subscriber on the right side. The arrow indicates the direction of the message. Following the time sequence diagram is a table that presents more detail about the messages and their content.

Table 4-1:Description of Sequence of Messaging for Service XXX

Example for service XXXX	
Actor	**Description of Actor**
Service provider	Meter data management agent or AMR Co
Meter 1, 2, 3	Meter 1, 2, 3

Scenario 1 for service XXXX	
Message ID and Description	**Message Detail**
(1) Service provider requests data from all subcribers' meters.	Get("All", "meter")
(2) Meter returns requested information	GetResponse (<data>) <data> would contain request data

4.1.4 Description of Generic Services

The time sequence diagrams described in the previous section are intended to illustrate the sequence of messages that implement the service(s). To provide some level of detail, generic services are provided in the message detail that relate to the models presented below. These services contain an abbreviated set of communications pseudo-services and arguments to simplify the presentation.

In an implementation of the services more detail about the usage of transport services, security and other related issues is required to completely, and interoperably, define the service. The conventions used in this section are to facilitate the presentation of the services and not to completely describe them.

The pseudo-services described in this section use a convention for the destination of the message that supports the use of "All" to imply that the message is to be delivered to multiple destinations. Whether these messages should be implemented using unicast, multicast, or broadcast services is not implied by this usage.

The following messaging exchanges are depicted in the time sequence diagrams:

- The writing of a remote objects value: Set, SetResponse
- The reading of a remote objects value : Get, GetResponse
- The reporting of a remote objects value: Report

Set (<destination>, <object>, <data>) Used to write data to a remote server by object name and value where:

<destination> is the logical address of the server containing the object to be set; the value "All" represents a broadcast message,

	<object> is the name of the remote hierarchical object to be set, <data> is the data to be written.
SetResponse()	This is an acknowledgement of the receipt of the Set message. Note that broadcast and multicast Set() messages may not require an acknowledgement. The details of when and how this is required is beyond the scope of this section.
Get (<destination>, <object>)	Used to read data from a remote server by object name and value where: <destination> is the logical address of the server containing the object to be set; the value "All" represents a broadcast message, <object> is the name of the remote hierarchical object to be set.
GetResponse (<data>)	Acknowledges a Get request and provides the requested data, where: <data> is the requested data.
Report (<destination>, <object>, <data>)	Used to announce unsolicited data to one or more remote clients by object name and value where: <destination> is the logical address of the client(s) receiving the object data; the value "All" represents broadcast message, <object> is the name of the remote hierarchical object that contains the data, <data> is the data provided.

4.2 Defining New Services

Potential new services are defined as services that have been identified in the literature or in personal conversations with market leaders in the control industry as technically feasible with some degree of economic viability. In the interest of capturing a wide field of services, we may discuss services that may not be economically viable – at least not now - or only viable under special market conditions. It is the intent of this project to be as comprehensive as possible. Because the economics of future services are difficult to assess at this point, we do not attempt to assess any profitability or economic viability of any service proposed.

The underlying assumptions for this analysis include a regulated market structure as currently exists, as well as likely scenarios of a retail electricity market. We have assumed a retail model based on open retail access and in which new market entrants such as energy service companies and other utilities can offer services beyond their traditional service territory lines. It is also assumed that the distribution company remains to some degree regulated. The difference between the retail model and the existing regulated marketplace is that service providers in the retail model may need a greater degree of flexibility to accommodate different transfer media and protocols as they provide service to customers scattered over several distribution company service territories. The functional requirement to interface with several communication protocols is derived from this need to accommodate several communication technologies. This is an important difference from the old model in which the transfer medium and information technology is less diverse.

4.3 Description of Target Customers

Target customers are commercial and industrial buildings and facilities that are equipped with direct digital controls (DDC) and a gateway device that connects the building's LAN with a WAN of the utility or energy service provider.

In many cases, connectivity with the customer site is accomplished through use of PC at the customer's premises with suitable WAN connection and software. However, in smaller applications, a dedicated gateway device may be required. Ultimately, the gateway function may be accomplished through the addition of a modem and firmware in the building's DDC panel.

The information services discussed below are generally fully automated, avoiding any human intervention. In some cases, however, the customer is asked to provide information for the service to operate. This information is limited to the economic assessment of increasing levels of load reduction (i.e., demand elasticities). This means that the customer must provide a monetary value, which is assigned to a given load reduction quantity. In another case, the customer is asked to establish a load reduction priority list, which requires the customer to identify systems or individual pieces of equipment that are shut off or modulated.

The proposed information services are provided by the utility, energy service provider, or a communication provider.

4.4 Revenue Metering Functions

In preparation for the deregulation of the electric power industry in California, Massachusetts, Rhode Island, and other states, intense debates among the stakeholders in the metering industry have produced detailed specifications of physical properties to be metered as well as communication protocols and requirements for the transport of metering data across WANs. On March 6, 1997, the California Public Utility Commission (CPUC) ordered the three large investor owned utilities, Pacific Gas and Electric Company (PG&E), San Diego Gas and Electric Company (SDG&E), and Southern California Edison Company (SCE) to confer with interested parties and to develop the necessary standards for equipment and functions to ensure that reliable service to customers would continue, regardless of the metering service entity[4]. The Metering and Data Communication Standards (MDCS) Working Group was founded as a result of this CPUC order. The Working Group submitted its report to the CPUC in July 1997. This document is one of the most comprehensive reports on metering and data communication issues [MDCS, 1997]. The Working Group report, along with AMRA and IEEE standards, provides a guideline for the data modeling efforts of revenue meters [AMRA/IEEE SCC31, 1996].

4.4.1 Electric, Natural Gas, and Water Metering

Service Objective: The objective of this service is to transport electric, natural gas, and/or water data tables in the least complex fashion from the customer sites to the utility or meter reading agent.

Electric metering: The following electric meter types should be considered:

- polyphase meters
- bi-directional flow meters
- non-intrusive load monitoring meters.

[4] PG&E, SDG&E, and SCE (the UDCs) were ordered by Decision 97-05-039 (Ordering Paragraph 4) and Decision 97-05-040 (Ordering Paragraph 7.A.(1)), dated May 6, 1997.

Natural gas metering: Gas service metering encompasses any metering required to service all market sectors (residential, commercial, and industrial).
Water metering: Water metering services include flow and pressure and water quality parameters.
Enthalpy metering: Enthalpy flows to customers are metered for district cooling and heating applications.

System Objective: The meter reading device consists of the meter and a communication component. The objective of the metering device is to meter a physical property of a utility (e.g. electric energy and volume of water or natural gas) and store the meter data locally according to specific instructions that specify what and when to sample. The meter data are accessible through the communication component, which responds to an upload request by the service provider or the customer. Many WAN media are in use. Telephone line and radio frequency (RF), as well as power line carrier transport methods, are common. Cellular digital packet data (CDPD) systems, which overlay the cellular voice network to provide a wireless data network are emerging. This technology provides secure wireless packet data connectivity and is based on industry standard Internet protocol (IP).

Nature of Data Transport: Two-way communication is required to read meter data on demand. The meter reading agent sends a request message for reading a single meter or a set of meters, upon which the meter returns the requested data. For time dependent rate structures (time-of-use (TOU) and real-time pricing (RTP)), the meter's clock must be synchronized to a common clock. The meter reading agent provides the synchronization signals.

The meters may also be operated on a fixed meter reading schedule (e.g., at the end of a month) in which case, the meter would initiate the data transport without prior request.

Structure of the Data Object Model:

The meter model is composed of a translation of the ANSI C12.19 "Tables" performed as part of work in the Customer Interface Working Group of the Utilities Communications Architecture Forum[5]. The high-level structure of the basic meter model is shown below.

```
Meter
   |__Extents
   |__Cfg
   |__Status
   |__Regs
   |__<W, V, A, VAR,…>
   |__Dmd
   |__Cmds
   |__LPCfg
   |__LP1
   |__LP2
   |__LP3
   |__LP4
   |__PrevSeason
   |__PrevDmdRst
   |__SRReg
   |__Tables
```

Figure 4-3: ANSI C12.19 Based Meter Model

[5] UCA Forum operated from 1994-1998 under the auspices of the Electric Power Research Institute. Their work is presently being brought under the IEEE SCC36 "Utility Communication Architecture."

Extents
Maximum degrees of freedom for meter model. For example maximum number of measurements if the meter has programmable inputs.

Cfg
General configuration information about the meter.

Status
General status information about the meter.

Regs
Register data of the meter. This section provides summary results of measurements in the meter. For example power measurements, voltage, gas, water, etc… These structures are constructed as arrays of information grouped by category. For example all demand measurements, all accumulated values, …

<W, V, A, VAR>
The actual measurements of the meter would be found aggregated here by name.

Dmd
Demand control and status information.

Cmds
Commands to change the mode of operation of the meter.

LPCfg
Load profile recording subsystem configuration.

LP1
Load profile table 1.

LP2
Load profile table 2.

LP3
Load profile table 3.

LP4
Load profile table 4.

PrevSeason
Snapshot of register information from previous season.

PrevDmdReset
Snapshot of register contents at last demand reset.

SRReg
Self read register log.

Tables
Byte oriented interface to support the reading and writing of ANSI C12.19 Tables using full table and partial tables with offset and index count methods.

Time Sequence Diagram: Assume a customer selects a real-time pricing electric rate and the service provider reads the customer's electrical meters every night. At each reading, the service provider requests a 24-hour load profile stored in the meter for the previous day. The time sequence diagram below illustrates the exchange of messages between the customer's meter and service provider.

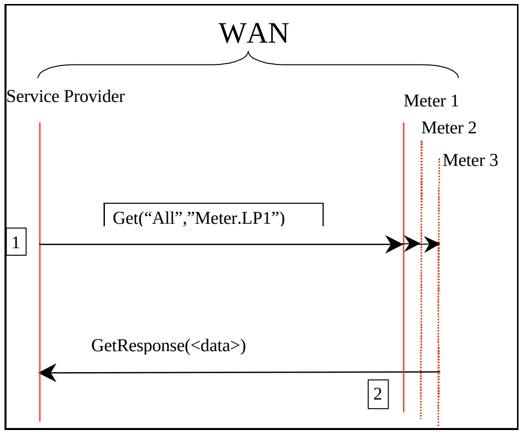

Figure 4-4: Time Sequence Diagram for Revenue Meter Reading

Table 4-2: Description of Sequence of Messaging for Revenue Meter Reading Service

Revenue meter reading time sequence diagram actors	
Actor	**Description of Actor**
Service provider	Meter data management agent.
Meter 1, 2, 3	Meter devices 1, 2, 3

Scenario 1: Requested reporting of power quality data	
Message ID and description	**Message detail**
1. Service request the previous day’s load profile.	Get(“All”, “Meter.LP1”)
2. Meter returns request load profile to requester	GetResponse (<data>) <data> would contain the hourly load profile

Embedded in the Get command of the request message is additional information pertaining to the start-time, end-time for the load profile request, and other information regarding the status of the meter. More detailed information about the data object model can be found in Section 6 and in the Appendix.

Bandwidth Requirements: Depending on the intervals between two consecutive meter readings, the data package may be considerable. Daily reading of 15-min. interval consumption data requires 24*4=96 data items comprising date, timestamp, and the metered property. Bandwidth requirements are low for communication between the meter and the first distributed processing unit (neighborhood server), but increase significantly at higher levels of the WAN topology as more servers feed meter data into the network.

Data Security Issues: The metered data of individual customers are considered proprietary. Secured communication using encryption methods are recommended for the data transfer.

4.5 Quality of Service Monitoring

Quality of service monitoring encompasses power quality, service reliability and outage detection of electrical services, as well as pressure transients and service disruption of natural gas and water supply lines. The quality monitoring could be extended to measure physical properties of the natural gas or water supplies. For instance, heat content of natural gas supply, or opaqueness or sediment content of the water could be trendlogged.

4.5.1 Power Quality Monitoring

Service Objective: The service provides monitoring capabilities of key power quality parameters for the purpose of establishing a common base for the nature and extent of power quality disturbances. To be effective in identifying and mitigating power quality problems, power quality must be monitored at the customer's service entrance and within the customer's facility for the purpose of isolating the origin of the power quality disturbance. Included in the power quality service are unsolicited power quality event reporting, power quality event staging, local power quality event storage and retrieval, and device synchronization throughout the WAN.

System Objective: The objective of the power quality monitoring system is to monitor disturbance on the power lines and record events after a trigger signal is given. There are two aspects to power quality monitoring. First, a disturbance has to be detected; and second, after the trigger is given, the ensuing event must be recorded and transmitted upstream to the service provider. The message of an event can be sent upon request or, in the case of an outage, the event is transmitted unsolicited. . Currently substantial efforts are undertaken in the IEEE SCC-22 Standards Coordination Committee to define clearly and rigorously power quality key parameters.

Nature of Data Transfer: Depending on the monitoring type (unsolicited versus solicited) the data communication can be one-way or two-way. For practical purposes, most of the communication technology of power quality equipment is capable of two-way communication. Power quality data may be appended or pre-pended to the metering data messages.

Structure of the Data Object Model: The data object model for this service has the following two components: (1) a power quality event (PQE) and (2) a power quality monitoring component (PQM). PQE is embedded in the PQM object. An overview of the high level structure of the model is presented below.

PQM
|__PQEvts
|__Trgs
|__ClrAllEvt
|__Rpt
|__Evt

PQEv
|__TypTx
|__SeqID
|__Nam
|__Mag
|__StTim
|__Loc
|__Polarity
|__SyncSrc
|__TrgTyp
|__TrgSrc
|__TrgVal
|__WrstVal
|__WrstTim
|__SpctCont
|__PtOnWav
|__Dur
|__Wav

Figure 4-5: Tree Diagram of the PQM and PQEv model

PQM
Power quality monitoring model.

PQEvt
Array of events.

Trgs
Array of trigger descriptions.

ClrAllEvt
Clears all current events.

Rpt
Description of report.

PQEv
Power quality events. It characterizes the trigger and storage of a power quality event.

TxTyp
Type of power quality event.

[1]	PQTransientsImpulsive
[2]	PQTransientsOscillatory
[3]	PQVariationsShort
[4]	PQVariationsLong
[5]	PQVoltageImbalance
[6]	PQHarmonics
[7]	PQInterharmonics
[8]	PQNotching
[9]	PQNoise
[10]	PQWaveshape
[11]	PQPowerFrequencyVariations
[12]	PQLimitThreshold
[13]	PQTimed

SeqID
Identifies frame to which this event is associated. A frame is a set of events and waveforms that occurred in a contiguous span of time.

Nam
Specifies the reference of the measurement the event occurred on.

Mag
The maximum absolute value the transient reached, e.g., peak voltage or current.

StrtTim
Absolute timestamp of transient event.

Loc
User defined identifier that references site specific data.

Polarity
Contains the direction of the impulse with respect to the instantaneous value of the parameter being measured just before the impulse occurred. For instance if the instantaneous voltage just before the event was -100 volts and the maximum excursion voltage is +10 volts, then polarity is negative. The allowed values are positive = TRUE, and negative = FALSE.

SyncSrc
Describes how the monitor sampling is synchronized with the waveform being sampled. The monitored source used for synch is referenced here. The reserved name “INTERNAL” signifies an internal timebase.

TrgTyp
Describes why the event was captured. The allowed values are: HIGHTONORMAL, NORMALTOHIGH

TrgSrc
Specifies the source that triggered the event.

TrgVal
Specifies the threshold value crossed.

WrstVal
Extreme value measured.

WrstTim
Timestamp of extreme value.

Spectralcontent
Rise time in nanoseconds of the leading edge.

PtOnWav
Time in fractional seconds from last previous positive zero crossing to peak value.

Dur
Width in nanoseconds of entire transient.

Wav
containing the actual waveform data itself in binary large objects (BLOBS).

Time Sequence Diagram: There are two typical applications for the power quality reporting: (1) solicited and (2) unsolicited reporting. The first scenario in the time sequence diagram describes the solicited report. The second scenario illustrates the self-reporting feature of the service that transmits a report after an event has occurred.

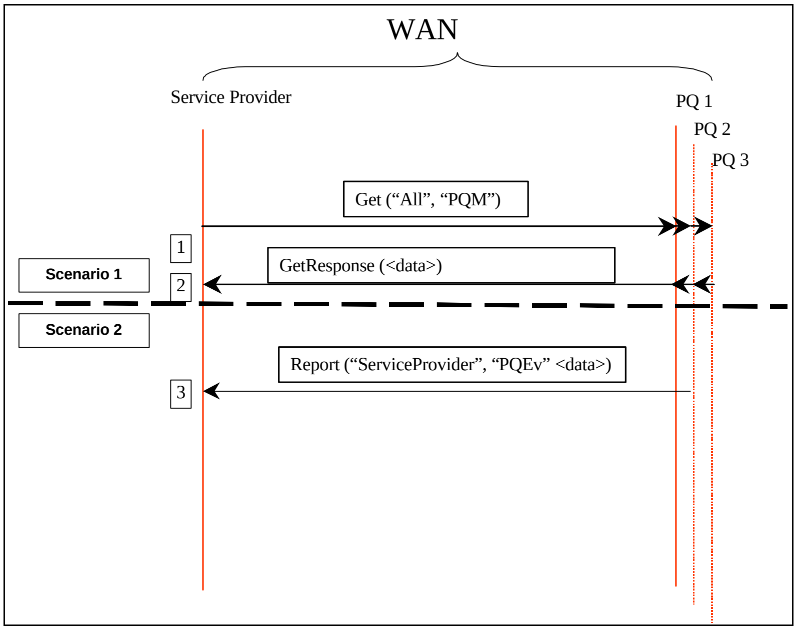

Figure 4-6: Time Sequence Diagram For Power Quality Monitoring

Table 4-3: Description of Sequence of Messaging for the Power Quality Monitoring

Power quality time sequence diagram actors	
Actor	**Description of Actor**
Service provider	Meter data management agent.
PQ1, 2, &3	Power quality monitoring equipment (Generally it is part of an electrical meter)

Scenario 1: Requested reporting of power quality data	
Message ID and description	**Message detail**
(1) Service provider requests power quality events from all customers	Get(“All”, “PQM”)
(2) PQ device returns requested data	GetResponse(<data>)

Scenario 2: Unsolicited reporting	
Message ID and description	**Message detail**
(3) PQ2 device triggers an event and transmits power quality report to service provider. Unsolicited reports are triggered by exceeding thresholds of power quality parameters	Report(“ServiceProvider”,”PQEvt” <data>)

Bandwidth Requirements: Bandwidth requirements are similar to those of the metering service. If both services are combined, bandwidth requirements increase with the sum of each individual transfer data requirement.

Data Security Issues: Power quality data of individual customers is considered proprietary. Data encryption may be required for the data transfer.

4.6 Pricing Information Systems

Real-time pricing (RTP) information broadcasting services currently exist and have been widely applied to commercial/industrial and residential customers. The dissemination of RTP information is accomplished using a broad spectrum of technology ranging from a ‘low tech’ solution of faxing the 24-hour price data for the next day to a dynamic data exchange (DDE) approach in which on-line price data are instantly updated at the customer’s EMCS software. Most commonly fax or e-mail services are used to transmit the hourly prices to the customers. PG&E, for instance, provides a remote printer at the site of the customer to print out a hard copy of the real-time prices for the next day [PG&E, SCHEDULE A-RTP, 1998]. A transmission mechanism that provides receipt notification by the customer after receiving the next day’s rates or any other update is desirable. Because of the multitude of RTP rates used, it is further desirable to have a versatile data object available that supports all of the currently used RTP rate structures to facilitate the ease with which the RTP rate can be read and processed properly at the customer’s site.

The RTP rates are generally structured in fixed and variable tariff components. The fixed component generally represents the capital cost recovery of generation, and transmission and distribution capital investments. The variable cost captures the cost associated with the generation. California utilities base their variable cost on the hourly 1-day-ahead prices, as determined by the Power Exchange [PG&E, SCHEDULE A-RTP, 1998]; [SCE, HPX, 1998]; [SDG&E RTP-1, 1998]. British Columbia Hydro and Power Authority, for instance, references their variable cost on the Dow Jones Mid-Columbia Firm Electricity Price Index [BCHydro-1848, 1998]. Other utilities perform a utility-wide or power-pool-wide marginal cost analysis to determine the variable cost component of the real-time pricing rate [CG&E, 1997]. Most of the RTP rate schedules have a revenue neutrality clause, which requires the utility to charge the customer the same price under the RTP rate as the customer would have been charged using a conventional rate, provided that the customer’s consumption profile is identical to an established baseline. The customer baseline (CBL) is commonly used to achieve revenue neutrality. It is generally established by hourly consumption data recorded over a period of 1 year. The variable rate component of the RTP tariff then applies to the difference between the actual load profile and the CBL. If the customer’s load profile exceeds the CBL, the RTP rate times the differential is charged to the customer. Conversely, if the customer’s load stays below the CBL, a credit is incurred.

Service Objective: Provide customer with dynamic pricing information of electric power. The objective of this dynamic pricing scheme is to encourage the customer to perform load management strategies to lower the electric demand during high price periods. Therefore, most target customers are large customers with some flexibility to manage the electric load.

It is currently customary to provide RTP rates for each hour of the next day, although shorter time increments are possible. The RTP rate schedule could be updated with and without prior notification. Rate schedules could be furnished one or more days in advance. It is customary that RTP rates valid for the next day are delivered in the afternoon or evening of the day before.

System Objective: Transfer of pricing data from the energy provider to the customer with receipt notification. The system must log any transmission of rates and updates for bill settlement.

Nature of Data Transfer: The data transfer is bi-directional. Pricing information is sent from the service provider to the customer. The service provider receives an automated notification that the messages have been received. For billing computation, the customer's electric meter sends consumption data and other information relevant for the billing to the service provider. The data transfer typically occurs once a day by a specified time. Rate updates can occur multiple times during the day with and without notification.

Bandwidth Requirements: Depending on the frequency of the RTP price delivery, the bandwidth requirements may vary; however, the data transfer rates are expected to remain low.

Data Security Issues: Depending on the CBL delivery arrangement, RTP messages could contain confidential information. If a daily CBL is transmitted along with the daily pricing data, secured communications are likely to be required. The rate information itself is generally not confidential and, therefore, may not need secured communication lines for delivery.

Structure of the Data Object Model Tariff: The tree diagram below illustrates the major components of the proposed Tariff data model. Details can be found in Section 6.

```
Tariff
    |___ID
    |___NumMx
    |___Cmps[1..NumMx]
          |_Pricing
          |_Schd
          |_RefProf
```

Figure 4-7: Tree Diagram of the Tariff Model

<u>Tariff</u>
The complete description of the dynamic electric rate tariffs.

<u>ID</u>
Identifier of tariff. For instance the rate schedule name could serve as an ID.

<u>NumMx</u>
Number of descriptive components of this tariff. For example, a tariff based on consumption pricing and demand pricing would be represented by NumMx of 2.

<u>Cmps[]</u>
An array of RTP component structures each of which describes price components. It uses NumMx as a dimension index of the array.

<u>Pricing</u>
Contains the pricing information of each element of Cmps. It embodies a data structure itself.

<u>Schd</u>
Contains a description of the real-time pricing schedule for the price component.

<u>RefProf</u>
Contains a reference load profile or customer baseline (CBL) for use in computing differential contributions to bill.

Time Sequence Diagram: Assume that a Tariff data object has been defined, comprised of a 24-hour consumption price structure and a monthly electric demand ratchet. In this case, the first element of the Cmps array could be the 24-hour consumption (kWh) price component. The second element would then be the demand charge. The demand component would have only a price component and no schedule (Schd) or reference profile (RefProf) associated with it. The 24-hour consumption price component would have a pricing (Pricing) and a schedule (SchD) component.

The following time sequence diagram illustrates some potential applications of the model and how messages are being transmitted.

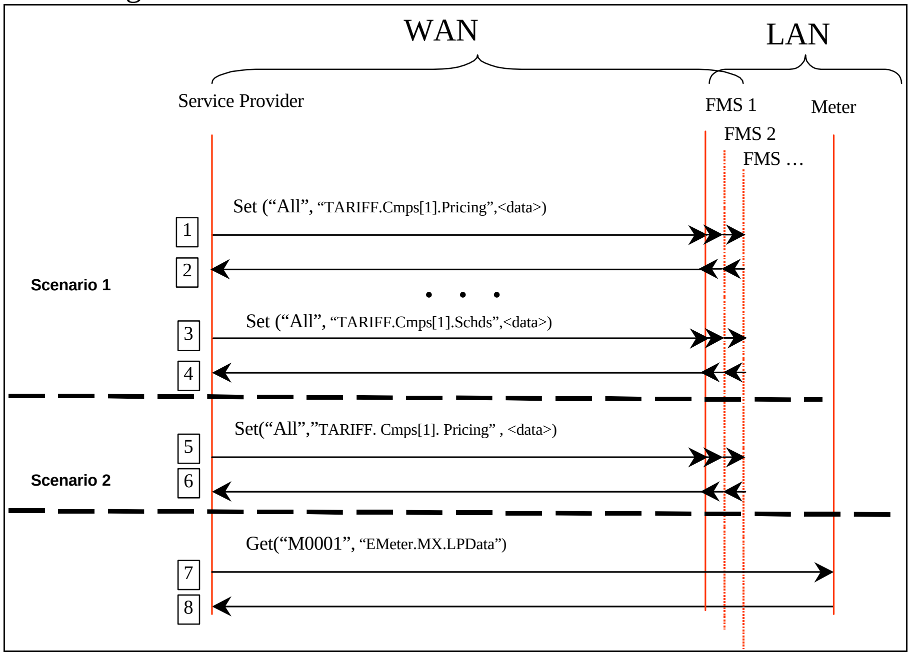

Figure 4-8: Time Sequence Diagram For the Transmission of Pricing Information

In the above example of the time sequence diagram, it is assumed that the demand component does not change. Hence, there is no need to update that component. In the first scenario, the 24 price and corresponding time information items are set and transmitted. The facility confirms the receipt of the message. In the second scenario, it is assumed that the schedule does not change and; therefore, only the price component is transmitted. It is typical for currently used 24 hourly RTP rates to schedule the starting time of each rate bin on the hour. In this case, a default schedule may apply, which does not need to be re-transmitted every day when the new pricing information is broadcast.

For billing computation purposes, the service provider sends a request for load profile data to the electric meter, upon which the meter returns the requested data. Details of the messages of Figure 4-8 are shown in Table 4-4 below.

Table 4-4: Description of Messaging Sequence for RTP Information Service

Power quality time sequence diagram actors	
Actor	**Description of Actor**
Service provider	Meter data management agent.
FMS 1 FMS 2 FMS 3 Meter	Facility management system in facility 1 Facility management system in facility 2 Facility management system in facility 3 Meter in facility 1

Scenario 1: Distribute the pricing and schedule for the tariff	
Message ID and description	**Message detail**
1. Service provider sets and sends the pricing component. For example, <data> would include a data structure with 24-hour prices	Set("All", "Tariff.Cmps[1].Pricing", <data>)
2. FMS sends acknowledgement to service provider	
3. Service provider sets and sends the scheduling component of the tariff.	Set("All", "Tariff.Cmps[1].Schd", <data>)
4. FMS sends acknowledgement to service provider	

Scenario 2: Distribute only the pricing table for day ahead notification	
Message ID and description	**Message detail**
5. Service Provider sends the pricing component. For example, <data> would include a data structure with 24 price items.	Set("All", "Tariff.Cmps[1].Pricing", <data>)
6. FMS sends acknowledgement to service provider	

Read the meter data for the bill computation	
Message ID and description	**Message detail**
7. Service provider sends request to meter for load profile data	Get("M0001", "EMeter.MX.LPData")
8. Meter responds with load profile that can be used to produce bill	GetResponse(<data>)

4.7 Rate and Current Bill Information Services

Service Objective: This rate information service provides utility rate information on any schedule offered by the service provider. The service requires a request by the customer and delivery by the service provider to the customer. Currently, this service is often implemented as a web-based application on the service provider's web-server.

In addition, the Tariff model supports the distribution of billing information so that customers can dynamically produce estimated bills that can be used in an energy management strategy. The estimated bill can be computed from the Tariff data structure for each tier-based component by multiplying the rates with consumption data for each time period defined in the rate schedule. Detailed information can be found in Section 6.6.

System Objective: Transmits rate information from the service provider to the requester and generates current bills.
Nature of Transfer: Two-way communication for request and delivery of rate information.
Bandwidth Requirements: Depending on the complexity of the rates and the frequency of information requests, the bandwidth requirement can be relatively high. The request frequency could be high at times when rate changes occur.
Data Security: Rate schedules have been public information subject to approval by State regulatory authorities. Data security is generally not considered for this information. For bilateral contracts, rates are negotiated on a customer-by-customer bases. Secure communication lines may be required for bilateral contract information.
Structure of the Data Object Model: The Tariff model can be used for this service.

Time Sequence Diagram: The time sequence diagram illustrates the rate request messaging. The rate information request and the delivery of rate information is illustrated below.

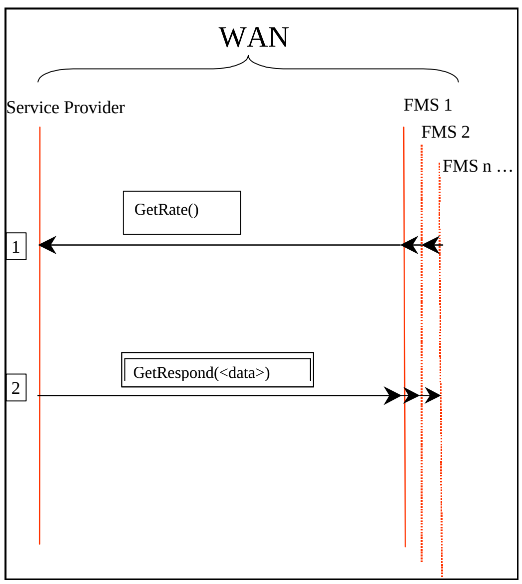

Figure 4-9: Time Sequence Diagram Rate Information Service

Table 4-5: Description of Sequence of Messaging for Rate Information Service

Rate information time sequence diagram actors	
Actor	**Description of Actor**
Service provider	Meter data management agent.
FMS 1, 2, 3	Facility management system in facility 1, 2, 3

Requested rate information	
Message ID and description	**Message detail**
1 FMS request rate information	GetRate()
2 Service provider delivers rate information	GetResponse(<data>”)

4.8 Load Management Functions

4.8.1 Load Limiting and Load Management

Load management methods have been applied under various rate structures. Motivated by monetary rewards, the operator limits peak loads or shifts electricity consumption from peak to off-peak periods. Time-of-use (TOU) rates or real-time pricing (RTP) rate structures offer these incentives. Generally, the control actions for load management are initiated from within a building or facility through energy management and control systems. It is the building/facility engineer who decides how to manage the loads. Flexible and dynamic load limiting functions have recently been automated in sophisticated energy management and controls software offered by various vendors [Honeywell, 1996], [ECAM, 1999].

The load management function could be transferred from an on-site point of control to a central site, such as the utility's distribution control center or an energy service company's energy control center. Load management centers could be envisioned where energy service companies manage aggregated or individual loads. This would require remote control and load management capabilities from a central point. Economies-of-scale benefits could be utilized in managing many participants' loads. With each additional participant to a load pool, the degree of freedom in the load management increases. This results in a greater degree of flexibility to optimally control the aggregated load of the pool. For large enterprises such as national franchises or large property management companies, who operate facilities and buildings across time zones, the time difference when each participant's demand peak occurs could be utilized for optimal load management strategies. Perhaps greater benefits resulting from economy-of-scale could be realized by centralizing maintenance and alarm response services, which would have a direct and measurable O&M cost reduction impact by reducing maintenance staff.

The target customer is primarily defined by his/her flexibility to manage load and by the size of the load. Generally, industrial customers and large commercial customers are more likely to be selected because of economy-of-scale principles. Second, the location of the customer is of significance. In areas where there exists power delivery 'bottlenecks,' load management strategies yield the highest cost savings. These areas tend to be high-density downtown areas or any other high growth concentrated demand area.

Service Objective: The objective of this service is to reduce facility operating costs by providing load management services from a single control center. The load limiting and load shedding strategies could be envisioned as part of the broader operations and maintenance service contract that ESCOs could offer. Pro-active load management requires an active load control engagement by the control center necessitating that the ESCO thoroughly understand each individual customer's load flexibility and anticipated load demands.

System Objective: The objective of the system is to perform load management strategies from a remote site to all participating members of a load pool. This requires access to the on-site EMCS or to a gateway that connects to the equipment communication busses with full control privileges. In most cases, the point of contact to the building control network is a PC that provides the gateway to the facility's LAN. After the initial contact at the remote site, the control center issues a load management request, which will be processed on-site, and results in some pre-defined control actions. Load management scenarios are defined that are associated with specific load reduction levels for each site. For instance, the following three scenarios could be postulated. They are listed in increasing load levels.

- do nothing
- moderate load reduction
- high load reduction.

Each facility manager assigns control actions associated with the level of the reduction request. The absolute load reduction in each reduction request depends on each participant's load management flexibility and the timeframe over which the load reduction is requested. For instance, with sufficient lead-time, an industrial customer may be able to alter manufacturing schedules to defer loads to off-peak periods. With little or no prior notification, the load shifting capabilities are reduced; however, a thorough analysis may still reveal electrical processes that may be temporarily stopped and deferred to a later time.

Nature of Data Transfer: Access to the EMCS requires two-way communications. The control center initiates the load reduction requests and the remote site responds with a compliant or non-compliant message. In the compliant case, the pre-defined control actions are executed on-site. Non-compliant messages are sent back to the control center. System response, as measured by total facility demand (kW), can be requested via a reading request of the main meter.

Bandwidth Requirements: The load management directives of load reduction targets are not data-intensive nor are they expected to be transmitted frequently. Therefore, the bandwidth requirements are minimal.

Data Security Issues: To protect customers' plant control systems, secured data links are necessary.

Structure of Data Object Model: Proposed are the following two models: 1) DLC to support load limiting control and 2) RmtMgmt to provide remote load management capabilities. For more detail on the data object models and the use of them see Section 6.7.1.

DLC model:

```
DLC
|__PctFullDty
|__DtyWnd
|__DtyDur
|__StartTim
|__Rand
```

Figure 4-10: Tree Diagram of DLC Model

<u>PctFullDty</u>
Percentage of full duty cycle to attenuate consumption.

<u>DtyWnd</u>
Time window over which the PctFullDty cycle is to be realized. The EMCS decides whether this is accomplished via cycling or modulation of the process. For instance, assume that an instance of the DLC model is sent to a residential customer for load management of the air-conditioner (AC). The value of DtyWnd=30 minutes and PctfullDty=0.5. Provided that the residential AC can only be turned on or off, then the load management target can be achieved by operating the AC in the following mode: 15 minutes runtime and 15 minutes downtime over a period of 30 consecutive minutes. There are an infinite number of modes possible. The unit of DtyWnd is given in minutes.

DtyDur
The total duration of this direct load control command as measured from the StartTim (not the randomized adjustment).

StartTim
Start time for this direct load control command.

Rand
A number of minutes to randomize the start time. A value of 0 means no randomization. A number greater than zero implies that a random number from zero to that value is added to start time to determine actual start time. Note that this implies start times always greater than or equal to StartTim.

RmtMgmt model:

```
RmtMgmt
|__NumParms
|__NumLvl
|__CurLvl
|__CurParms
|__Schd
|__Parms
|__NumOcc
|__NumOvr
|__RT
|__RTOvr
```

Figure 4-11: Tree Diagram of RmtMgmt Model

NumParms
Number of parameters per level.

NumLvl
Number of levels defined.

CurLvl
The current level and set of parameters loaded.

CurParms
The current parameters used for control by the device.

Schd
Schd describes the changes in the current parameters. The Evt code for the TimEvts represents the selected value of the set of Parms to be used. Note that because of the flexibility of the Schd component, either one-time or recurring timed programs are possible.

Parms
An array of sets of parameters to be used to control the device. In essence, these represent a set of supervisory setpoints to be used by the control algorithms of the device. The elements of the arrays are all dimensionless floating point numbers that can be interpreted by prior agreement between the supervisory controller and the management of the field devices to be controlled.

NumOcc
Number of occurrences of change in the CurParms resulting from scheduled or direct overrides to the CurLvl component.

NumOvr
Number of overrides of the operating parameters affected by the device owner. This statistic can be used in a monitoring regime that might permit, for example, “x” overrides per billing period.

Rand
Randomize the scheduled transition times by a number of minutes between zero and this value. The purpose of the randomization parameter is to spread transitions over a period of time to minimize large discontinuities in the consumption of a utility resulting from synchronization of scheduled transitions over a wide area.

RT
Run time of the managed device.

RTOvr
Total run time during local override conditions.

Time Sequence Diagram:

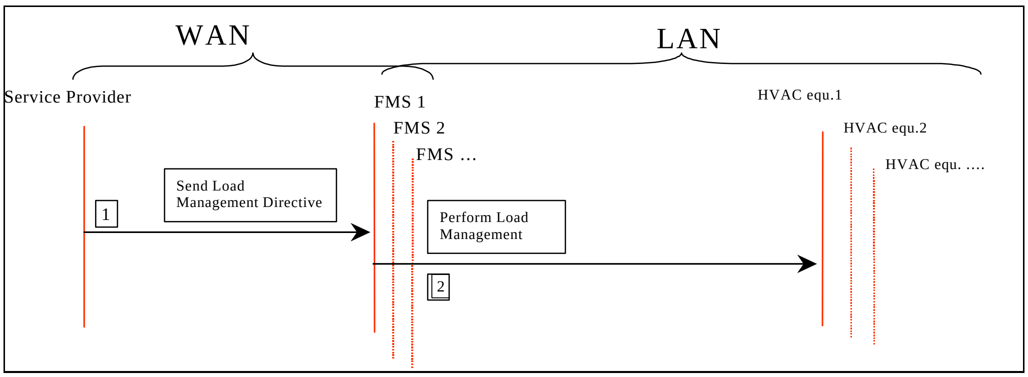

Figure 4-12: Time Sequence Diagram For Direct Load Management Services

Table 4-6: Description of Sequence Diagram For Direct Load Management

Direct load management time sequence diagram actors	
Actor	**Description of Actor**
Service provider	Meter data management agent.
FMS 1, 2, 3	Facility management system in facility 1, 2, 3

Send out load management directives	
Message ID and description	**Message detail**
1 Service provider sends load management directive with target reduction to FMS.	Set(“All”,<data>) <data> could include: ID number of equipment to be turned off Start time of turn-off End time of turn-off Reduction target
2 FMS determines which equipment to be used to load management and how to control it to achieve reduction target	Equipment specific control messages. E.g., for variable speed drive equipment, control message could be “change rpm to xxx.” For constant speed equipment, FMS would send “turn-off”, “turn-on” signals such that the load reduction on average over specified period is met.

4.8.2 On-Site Generator Control

On-site generation is used as a load management measure that can reduce electricity cost for the customer by reducing the total facility peak load and energy requirements during peak periods.

On-site generation can also be of value to the utilities by deferring upgrades of distribution facilities to accommodate load growth.

On-site generation entails the use of an emergency generator, co-generators, or dedicated peak-clipping generators. The electricity generated on-site satisfies a portion of the total load at any given time and, thus, is used to minimize the requirement for load supplied by the utility to a customer. In some cases, generation of the electricity may be larger than the customer's load requirements, in which case electricity can be fed back into the distribution systems.

Electric Power Research Institute has been actively involved in R&D efforts and market assessments of the distributed generation technology, which is a broader term for the small on-site and off-site generators that are of strategic importance for the reliability of the distribution network. Distributed technology has received general recognition as a cost competitive niche market technology for grid support and deferment of large transmission facility upgrades. The recognized market niches are congested urban areas with growing peak electric demands, where on-site generation can significantly support the distribution network by reducing peak load demands. Active research is being performed for the development of cost-effective fuel cell technology and gas microturbines (<1 MW), which are dispatchable by the utility [EPRI, 1997c].

On-site generation as a load management measure requires that the generator is operated in parallel with the utility supply. To maintain its main function as an emergency power supply backup device, the generator must also be able to provide electricity exclusively to dedicated circuits such as emergency lighting, fire and safety systems, and elevator control, in cases of emergencies. The electrical switchgear necessary for this application must be able to switch between the two modes of operation.

The control capabilities can either be limited to the local facility EMCS or extended to allow limited dispatchability by the utility. The utility would typically limit use of the generator to a maximum number of hours, which is determined by regulatory authorities that impose emission standards on fossil-fueled generator equipment. Generation technologies with no or minor pollution emission, such as fuel cells or renewable energy technologies, may be excluded from these operational restrictions.

Service Objective: The objective of on-site generation control by the utility is to create monetary rewards to end-users when utilizing their facility assets for the common good. This service is a direct load control measure that is under the control of the utility distribution company. The main incentive for the utility to engage in a partnership arrangement with a customer is to defer large capital investments to pay for upgrades of the distribution facilities to accommodate growing load demands. This service is particularly desirable in high-density urban areas, where line upgrades are relatively expensive for the utility. To create the necessary incentives for the customers to explore the merits and cost savings opportunities, the utilities need to offer attractive cost savings opportunities for participating customers. Incentives are generally offered as a credit based on the load relief the generator may offer.

System Objective: On-site generator control provides the utility with external dispatchable capacity that is in proximity to the load centers. The on-site generator must be equipped with the paralleling switchgear that enables the generator to operate in parallel with the utility supply. Closed loop power control is required for synchronization between the utility power and the emergency generator. Typically power control features include: proportional/integral/derivative (PID) control of generator power levels, volt-ampere reactive (VAR) or power factors to maintain voltage, and frequency stability. The control technology generally includes paralleling protective relay features to protect the on-site and utility distribution equipment. These include:

frequency, phase and voltage matching synchronization between the utility source and the on-site power generation, over and under voltage and frequency protection, and reverse power protection, which avoids potential damaging effect on the electric circuitry.

Automatic transfer switches with voltage or watt monitoring devices sense power outages and direct the electric power to dedicated emergency circuits to supply power to emergency systems such as emergency lighting, elevator control, and fire protection and access control systems. Detailed specifications governing the operational requirement of the switchgear vary widely across building types. For instance, hospital facilities may have significantly more stringent requirements regarding the safeguard of emergency circuits than office buildings or industrial facilities.

The generator operation is monitored and logged. On-site control as a direct load control measure requires strict reliability requirements on the communication and generation technology to guarantee the availability of generation capacity not owned and maintained by the utility.

Nature of Data Transfer: On-site generator control requires two-way communication between the utility and the generator. Open-loop control actions such as start, stop, and other control commands, as well as system status inquiries are exchanged. System monitoring is required continuously to assure reliable service. The monitoring service is limited to alert and alarm messaging and system status reporting. Closed loop control for voltage and frequency synchronization is performed on-site and does not need to be exchanged over the WAN.

Bandwidth requirements: Bandwidth requirements depend on the level of sophistication of the generator monitoring. Advanced distributed generation technology (such as fuel cell generator or microturbines) may pose higher bandwidth requirements for monitoring the generator depending on the number of control variables. For direct control of an emergency generator, it can be assumed that the level of controllability would remain low, encompassing start and stop control actions and system status reports.

Structure of Data Object Model: The data object model for this service has six components: three measurement data models that describe the electric properties of the generator, one protective relaying data model, and two supervisory control and monitoring data models. Supervisory control commands determine the overall operational modes of the one or more generators. Supervisory and monitoring commands include:

- On/off switch of the generator
- Schedule for availability of control by third party
- Load management functions that specify the operational mode (e.g., baseload operation versus load-following and load sharing in case for several generators)
- Export of electric power into the grid
- Selecting and setting limit (upper and lower) values for tripping utility protective relays for load breaker and transformer
- Specifying monitoring functions and logging reports.

The measurement and protective relaying data models contain significant detail. For clarity of the presentation, only the monitoring (SYSMON) and supervisory control (SPVSGEN) data models are shown. Details on the entire set of data models can be found in Section 6.8.

```
SPVSGEN
|__ID
|__Numgen
|__KWAvail
|__ThirPtID
|__ThirPtNam
|__Gen
     |__On
     |__RmRT
     |__Avail
     |__OpMod
     |__Expt
     |__PrRl
     |__CumHr
     |__CumHrTl
     |__Mon
```

```
SYSMON
|__Name
|__NumMx
|__Comp[]
```

Figure 4-13: Tree Diagram of Supervisory Control (SPVSGEN) and Monitoring (SYSMON) Models

ID
Identification of site on which generator is located.

Numgen
Number of generators at site.

KWAvail
Currently available generator capacity in [kW]. This can include multiple generator stations.

ThirPtID
Third party identification. Third party is the entity with whom the owner shares control and dispatch privileges.

ThirPtNam
Name of Third Party.

Gen
Array of control, protective relaying, and monitoring information.

On
Operational status flag. Switch from True to False turns generator off. Switch from False to True turns generator on.

True: Currently Running

False: Currently Not Running

RmRt
Remaining run-time in hours. Contractual agreements may limit the total cumulative number of hours to operated during a 1 year period. For instance, for diesel fuel internal combustion engines, local air emission standards may limit the total number of run-time per year.

Avail

Availability schedule. This variable is a structured variable of class ‘sched’ as described in earlier chapters. The schedule indicates scheduled maintenance or other down time during which the generator is not available for remote control.

OpMod

Load management or operational mode. The generator can be operated in the following modes:

1	baseload
2	load following

Expt

In case, the generation exceeds the load, the ‘Expt’ flag indicates if electric power is exported into the utility grid.

PrRl

Protective relaying measurements and threshold values are incorporated by reference here.

CumHr

Cumulative hours of operation under third party since Jan. 1 of each year or the earliest , beginning the first day of contractual agreement.

CumHrTl

Total number of generator’s run time.

Mon

Monitoring data class expressing measurements and limit values within which the engine is operated. Due to the multitude of different prime movers and generation systems (systems without prime movers such as fuel cells), a new data model class is proposed designed to express measurements and limits in general terms.

Name

System name.

NumMx

Number of subsystems to drive generator or enable the generator of electricity.

Comp

Array of subsystem component measurements – e.g. coolant temperature, oil temperature, engine speed, etc. Note that critical limits hl and ll are probably present.

Time Sequence Diagram:

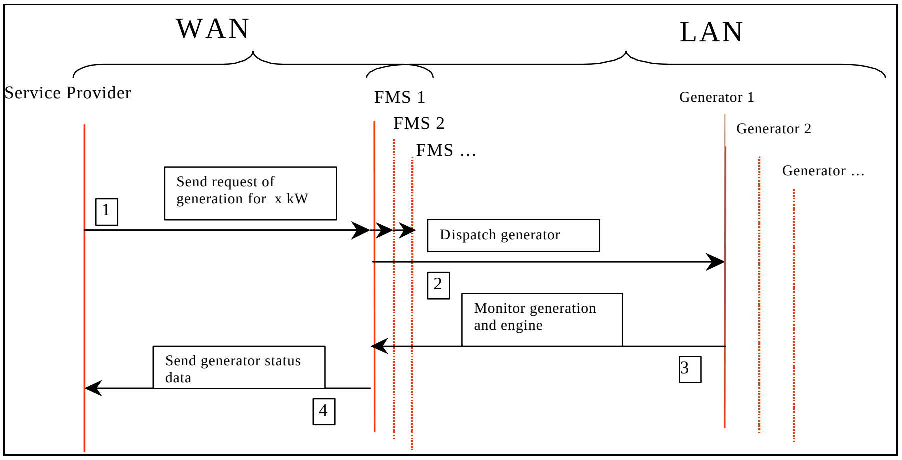

Figure 4-14: Time Sequence Diagram For On-Site Generator Control

Table 4-7 : Description of Time Sequence Diagram For On-Site Generator Control

On-site generation time sequence diagram actors	
Actor	**Description of Actor**
Service provider	Utility, ESCO, Load aggregator (LA)
FMS 1, 2, ,,,	Facility management system in facility 1,2, ..

Requested for on-site generation	
Message ID and description	**Message detail**
1 Service provider sends request for on-site generation	Set("C001","SPVSGEN" <data>) where <data> can include: ID number or customer classes (phase angle, etc) Start time of turn-off End time of turn-off
2 FMS selects generator and dispatches generator	Set("D001","SPVSGEN" <data>) where <data> can include: ID number of equipment
3 Generator reports generation and engine status information	Report("FMS1",SYSMON" <data>) where <data> can include: ID number of equipment kW, kVAR, kVA, PF, voltage, engine parameters
4 FMS reports to service provider generation information	Report("ServiceProvider",SYSMON" <data>) where <data> can include: ID number of equipment kW, kVAR, kVA, PF, voltage, engine parameters

4.9 Weather Information Services

Service Objective: The service provider offers a portfolio of weather report and forecast services. They could include: current weather reports and 24-hourly local forecasts provided once a day with different 12-, 6-, 3-hour, or hourly update options. A premium weather forecast service could be envisioned that would provide the customer a more accurate location-specific forecast. This premium service requires weather information from the customer's premises to adjust for micro-climate conditions not captured in the basic weather forecasts. Weather forecasts with micro-climate adjustment will result in a very accurate site-specific forecast suitable for short-term load prediction.

System Objective: The objective of the weather services system is to provide current weather reports and forecasts with hourly weather data updated on a regular basis. If a service with micro-climate forecast is subscribed, the forecast provider needs to collect local weather information. If the FMS of EMCS trendlogs outside-air conditions, these data could be transferred to the weather forecast provider. If monitoring equipment for these trendlogs are not available, the forecast provider may offer its own local weather stations with the necessary communication links.

Nature of Data Transfer: One-way communication for transfer of the reports is sufficient. If on-site weather data are transferred to the weather forecast provider for micro-climate forecasting, a two-way communication is necessary. Retrieval of the on-site weather information could be sent on a fixed schedule.

Structure of the Weather-Forecast DataObject Model: Two models are proposed for this service. The first data model provides a weather report, WEARPT, which contains current weather information. The second provides a weather forecast, WEAFCST, and contains periodic weather data profiles that are a time series of the structure of WEARPT.

The weather report model is primarily based on the METAR standard for weather reporting provided through the National Oceanic and Atmospheric Administration (NOAA). The Federal Meteorological Handbook (FMH) Number 1 titled, *Surface Weather Observations and Reports*, is the definitive United States standard for the Aviation Routine Weather Report and Aviation Selected Special Weather Report (METAR/SPECI) code formats. [FMH1, 1998]

In addition, the ASHRAE WYEC2 definitions were incorporated into the model [Stoffel Rymes, 1998].

The weather report model WEARPT is defined in the figure below.

```
WEARPT
|__Src
|__t
|__loc
|__Rad
|__Illum
|__Sky
|__ComDWC
|__Wind
|__Precp
```

Figure 4-15: Tree Diagram for the Weather Report Data Object Model

Src
Weather Bureau Army Navy (WBAN) identification number or the International Civil Aviation Organization (ICAO) station identifier coded as a visible string. WBAN numbers are 5 digits. ICAO identifiers are 4 characters.

t
timestamp of weather report.

loc
location for which weather report is valid.

Rad
Solar radiance. This is a structured data object encompassing the following items: horizontal, direct, extraterrestrial, and diffuse radiance.

Illum
Solar illuminance. This is a structured data object encompassing the following items: illuminances: horizontal, direct, diffuse, zenith.

Sky
Sky conditions. This structured data object includes: visibility, cloud cover, opaque sky cover, and snow cover.

ComDWC
Common descriptor of weather conditions. This structured data object encompasses the most commonly used descriptor of weather conditions. The structured object is listed below.

```
|__ComDWC
|    |__DryTmp
|    |__WetTmp
|    |__Bar
|    |__Hum
|    |__DegCool
|    |__DegHeat
|    |__HiTmp
|    |__LowTmp
```

Figure 4-16: Tree Diagram for the Weather Report Data Object Model

Where

DryTmp
Dry-bulb temperature.

Wetmp
Wet bulb temperature.

Bar
Barometric pressure.

Hum
Relative humidity.

DegCool
Degree cooling day (so far for the day of reporting).

DegHeat
Degree heating day (so far for the day of reporting).

HiTmp
Maximal daily dry-bulb temperature (so far for the day of reporting).

LowTmp
Minimal daily dry-bulb temperature (so far for the day of reporting).

Wind
Wind information. This data object structure includes wind direction, average velocity and gust velocity.

Precp
Precipitation information. This data object structure includes type of precipitation, total amount and current rate of precipitation.

A new weather forecast model WEAFCST is proposed to represent the time series of the weather report data object WEARPT shown above. The WEAFCST model specifies the starting time of the first reporting and the intervals for subsequence reporting events. More information on the WEAFCST model can be found in Section 6.

Time Sequence Diagram: The following time sequence diagram illustrates two scenarios for the applications of the model and how messages are being transmitted between the service provider and the customer. The first scenario assumes that the customer subscribes to a basic weather forecast service without the micro-climate adjustment. The second scenario describes the micro-climate forecast. It is further assumed that no receipt verification is applied in either scenario. The weather forecast is broadcast on a fixed schedule.

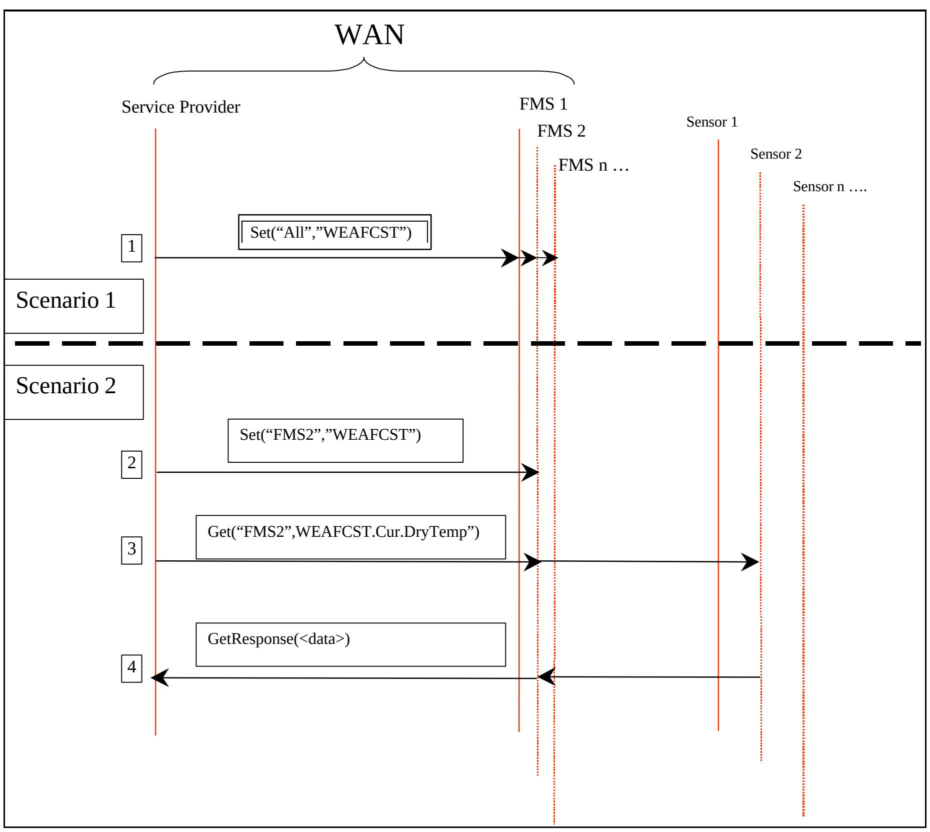

Figure 4-17: Time Sequence Diagram For Weather Forecast Services

In scenario 1, the service provider broadcasts the forecast to all subscribing customers within a region for which the basic forecast applies. NOAA defines the boundary of a weather forecast region. The destination “All” in the broadcast is, therefore, limited to those customers within that particular region.

In scenario 2, the forecast is addressed to one particular customer (FMS2) because of the very customer location-specific forecast that includes the micro-climate adjustment. To constantly monitor the accuracy of the micro-climate adjustment, the service provider requests the weather condition at the customer’s site. The on-site weather conditions measured at or in close proximity to the subscriber’s site are returned to the service provider. Gibson presented results of a micro-climate adjustment for peak load forecasting. He found a significant improvements of the peak load prediction by using the on-site dry-bulb temperature [Gibson, 1997].

The same data object model can be used for the return of the local weather conditions. In this case, the subscriber sets the value and returns the information back to the service provider. The table below illustrates the sequence of message exchange for this service.

Table 4-8: Description of Sequence of Messaging for Weather Forecasting Service

Weather forecasting time sequence diagram actors	
Actor	**Description of Actor**
Service provider	Utility, ESCO, weather service provider
FMS 1, 2, 3 Sensor 1, 2, 3	Facility management system in facility 1, 2, 3 Temperature sensor 1,2 ,3

Scenario 1: Distribute weather forecast to subscribers	
Message ID and description	**Message detail**
1. Service provider sets and sends the weather forecast. The weather forecast includes a data structure time series of, for example hourly projections for the next day or any shorter period.	Set(“All”, “WEAFCST”) All subscribers are within a local area to which the same forecast applies

Scenario 2: Distribute weather forecast with micro climate adjustment	
Message ID and description	**Message detail**
2. Service provider sets and sends to a specific subscriber (FMS2) the forecast.	Set(“FMS2”,”WEAFCST”)
3. Service provider requests local dry-bulb temperature from FMS2	Get(“FMS2”,”WEAFCST.Cur.DryTemp”)
4. Subscriber sets requested dry-bulb temperatures and returns temperatures	GetResponse(<data>)

Bandwidth requirements: The bandwidth requirements are minimal for both the transmission of the forecast as well as for the 24-hour on-site weather retrieval.

Data Security Issues: Weather Service data are unlikely to be secured over the network because of low risk of misuse of this information.

4.10 Energy Efficiency Monitoring

Service Objective: The objective of this service is to reduce the energy cost by monitoring total building and end-use energy efficiencies. The service is designed to identify energy efficiency degradation of individual end-uses such as heating, cooling, ventilation, lighting, vertical transport, and other processes. To accomplish this, end-use consumption data are processed to produce specific energy indices, which could be compared across subscribing facilities that have similar operational and schedule characteristics. These indices could be used for screening purposes to identify potential candidates for energy efficiency measures. The primary function of this service, however, is to monitor energy consumption over time to identify potential energy efficiency degradations.

This service is strictly an energy efficiency monitoring service and as such, it differentiates itself from fault detection and diagnostic (FDD), which commonly requires a higher degree of energy consumption information and detailed system process data. Energy efficiency monitoring attempts to identify changes in consumption patterns. FDD identifies system faults and postulates likely causes of the fault. The energy efficiency parameters postulated are commonly used consumption data, system efficiencies, energy indices, and energy intensities [EIA, 1995]; [NEMVP, 1996]; [Liu et al., 1997]; [Wolpert and Schroeder, 1998]. The indices postulated for this service include:

<u>Total Facility:</u>

<u>Consumption (Electric/thermal energy, volumetric or mass flow):</u>

- consumption per time interval[6] (e.g., kWh/h, kWh/year)
- consumption per unit of floor area per time interval (e.g., kWh/m^2/year)
- consumption per occupant per time interval (e.g.,kWh/occupant/year)
- consumption per unit of floor area per hour of operation (e.g., kWh/m^2/hour$_{operation}$). This index compensates for impacts of buildings/facilities schedules by normalizing the index by hours of operations over a given time interval (i.e., day, week, month, year) [EIA, 1995].
- consumption measured/ consumption predicted per time interval. For instance, $\left(kWh_{measured}/kWh_{predicted}\right)_{day}$. Several prediction tools based on artificial neural network approaches or statistical methods could be employed for this index [Rabl, 1998]; [Rabl and Riahle., 1992].

<u>Electric demand:</u> kW over time interval

<u>Sub-metered Circuits: (e.g., Lighting, Cooling Plant, Heating Plant, Ventilation)</u>

The same consumption-based indices can be used for any sub-metered circuits in the building or facility. In addition, the coefficient-of-performance (COP) for the cooling plants and system efficiencies such as for boilers and electrical motors or any other process for which input and output energy can be measured, could become a part of this service.

System Objective: There are two viable approaches for achieving the energy efficiency monitoring objective. First, detailed consumption data and equipment status information are transmitted from the buildings/facilities to a central control center for central processing. This

---

[6] Time interval could be any period. Generally, it is an hour, day, week, month, season, or year. But it could also be peak hours or off-peak hours.

would require a significant amount of raw data to be transported over the WAN. Alternatively, the energy indices are evaluated on-site and only the indices are reported to the control center.

The challenge of evaluating energy efficiency indices at the local EMCS is associated with the maintenance of this service, as the facility undergoes changes that impact the energy indices. For instance, data maintenance would be required to update indices that are normalized by floor space as the building undergoes extensions or changes in the leasing arrangements. For weather normalization, either outside conditions must be measured by the EMCS or an automated weather service provider must transmit weather data to the local EMCS. From a computational point of view, it is advantageous to distribute the data processing to the local EMCS and transmit the results rather than transmit large amounts of raw data over the WAN.

Nature of Data Transfer: One-way communication could be sufficient if the EMCS is scheduled for uploading of data at pre-determined times. It is more likely to employ two-way communication to allow the request of data at any time.

Bandwidth Requirements: The bandwidth requirements depend on whether massive raw data files or small files with energy efficiency indices are sent over the networks. For large buildings/facilities, raw data files may require a significant bandwidth for the communication technology.

Energy Efficiency Data Object Model: The energy efficiency data object model consists of two components: (1) a consumption event 'ConsEvt' and (2) an efficiency index 'ENEFF'. Consumption events are embedded in the ENEFF component.

```
ConsEvt                ENEFF
   |__d                   |__ID
   |__Typ                 | __NumMx
   |__NormId              |__Cmps[]
   |__TotCons             |__typ
   |__NormMx              |__EffIdx
   |__NormPred
   |__Prof
```

Figure 4-18: Tree Diagram of the Energy Efficiency Data Object Model

ConsEvt

Consumption event represents the consumption of a utility in conjunction with either time, persons, geographical, or functional usage. It contains time series of consumption items.

d

Description of consumption event.

Typ

Type of normalization of accumulated consumption described:

[1]	Not defined
[2]	By personnel
[3]	By equipment
[4]	By subsystem
[5]	By geographic reference – zone, floor, etc.

NormID

Normalization ID is used to express normalized energy indices (e.g. floor area or occupants). This can contain a visual string version of an object identifier or a simple name identifier. If the consumption event is associated with a customer account, for example, this ID would be an account identifier. If it were a geographic reference, it might be a string describing it such as "Conference Center."

TotCons
Total consumption described in Prof. Summation of individual events over a specific domain (e.g., time, geographic zone, etc.).

NormMx
Normalization measurement value – e.g., number of persons, surface area, number of zones.

NormPred
Predicted normalization value. It is used as a denominator for energy index and defined as measured consumption over predicted consumption.

Prof
Time series of measurements under this consumption event. Components of Prof describe the actual measurement being made.

ENEFF
Energy Efficiency DataObject model expresses energy efficiency index and necessary information on how to derive it. It is specified for any definable consumption event. For example, (1) total facility, (2) cooling plant, (3) heating plant, (4) ventilation, (5) lighting, etc.

ID
Identification of building for which EE DataModel applies.

NumMx
Number of metered systems/circuits, such as: total facility, cooling plant, heating plant, lighting, and any other metered process. It is the dimension of the Comps array.

Comps[1..NumMx]
An array of components of the ENEFF. Each element is an individual consumption event, ConsEvt, which contributes to the total aggregated consumption. For instance: (1) total facility, (2) cooling plant, (3) heating plant; (4) ventilation, (5) lighting, etc.

EffIdx
The energy index itself. It is a derived variable from consumption events and normalization data.

Time Sequence Diagram:

The following time sequence diagram illustrates some potential applications of the model and how messages are being transmitted.

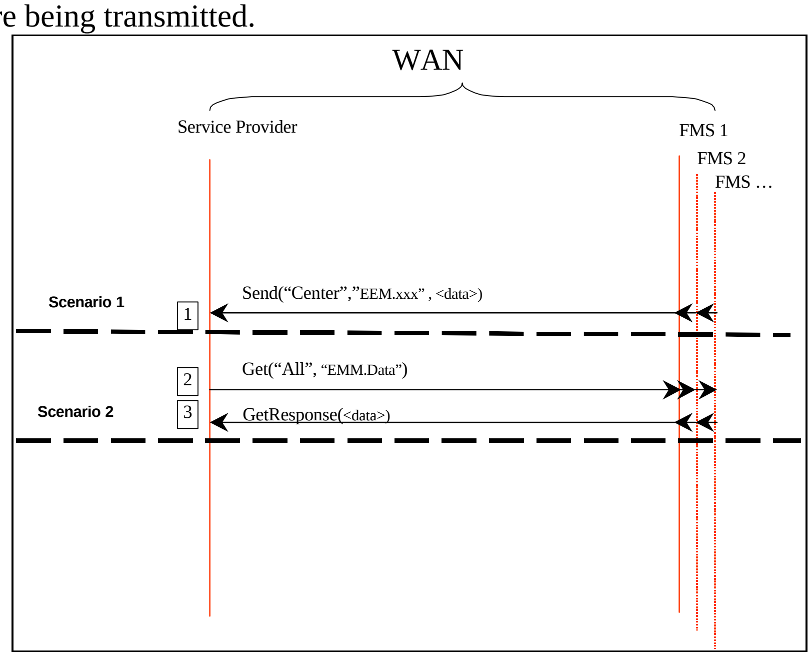

Figure 4-19: Time Sequence Diagram For Energy Efficiency Monitoring

Table 4-9: Description of Sequence of Messaging for Energy Efficiency Monitoring

Power quality time sequence diagram actors	
Actor	**Description of Actor**
Service provider	Utility, ESCO
FMS 1 FMS 2 FMS 3 Meter	Facility management system in facility 1 Facility management system in facility 2 Facility management system in facility 3 Meter in facility 1

Scenario 1: Scheduled uploading of energy data	
Message ID and description	**Message detail**
1. FMS sends energy data to service provider.	Report("Center", "EMM.xxx", <data>)

Scenario 2: Request uploading of energy data	
Message ID and description	**Message detail**
2. Service provider requests load profile for total Facility from all subscribers	Get("All", "EMM.yyy") EMMyy could be a load profile specifier
3. FMS returns load profile for total facility	GetResponse(<data>)

4.11 Indoor Air Quality (IAQ) Monitoring

Service Objective: The objective of this service is to document IAQ conditions for the purposes of conflict resolution for sick building syndrome claims, regulatory indoor air quality compliance, or advertising IAQ attributes of commercial real estate.

The regulatory aspect of the IAQ monitoring is complex because many Federal and State agencies have authority of various aspects of IAQ. There are 16 Federal agencies responsible for IAQ regulations for various pollutants and fields of applications [Environmental Reporter, 1987]; [The Commonwealth of Massachusetts, 1989]. The IAQ standards and guidelines are equally complex. The major contributing organizations are listed in the ASHRAE Handbook Fundamentals Chapter 9 [ASHRAE, Fundamentals, 1997] and can be summarized as follows:

- The Environmental Protection Agency (EPA) is the lead agency for Federal IAQ regulation. It has regulatory authority over toxic substances. EPA established National Ambient Air Quality Standards relevant for fresh air quality for building ventilation.
- The Occupational Safety and Health Administration (OSHA) sets Permissible Exposure Limits (PEL)
- The American Conference of Governmental Industrial Hygienists (ACGIH) publishes Threshold Limit Values (TLV). These TLVs are frequently agreed on to be reasonably safe concentrations of air emissions.
- The National Institute for Occupational Safety and Health (NIOSH) is the research arm of OSHA. NIOSH has developed criteria documents for specific substances and issued Recommended Exposure Limits (REL), which are generally below the TLV developed by the ACGIH.

Furthermore, the World Health Organization (WHO) has published air quality guidelines for Europe. The German research alliance (Deutsche Forschungsgemeinschaft) established

maximum concentrations levels for the work place (Maximale Arbeitsplatz Konzentrationen [MAK]). These levels are specified for an 8-hour exposure to substances in an industrial setting.
ASHRAE provided ventilation guidelines to address IAQ issues in buildings and facilities. ASHRAE Standard 62-1989 [ASHRAE 62, 1989] specifies minimum ventilation rates (cfm or L/s) and indoor air quality that will be acceptable to human occupants and are intented to minimize the potential for adverse health effects. ASHRAE Standard 62, 1989 has undergone a major revision in recent years. The proposed revision, however, has received a significant number of comments during the public review, which made it unlikely for approval by ASHRAE. An alternative approach has been adopted recently called the Continuous Maintenance Procedure, whereby the standard is updated via addenda to the existing Standard instead of entire revision. Several addenda have been proposed at this time and are in various stages of approval. The committee responsible for developing and processing these addenda expect to recommend republication of the standard in 2001, incorporating all the addenda approved to date.

The basis for the measurement parameters used for this service is derived from an US EPA document titled: "Building Air Quality, A Guide for Building Owners and Facility Managers" [EPA, 1998] and the ASHRAE Standard 62-1989 [ASHRAE 62-1989]. The EPA document is a practical guide to IAQ problem diagnostics procedures. Among the many air pollutants and air-borne toxic substances, there is a need to limit the number of IAQ parameters to be monitored for this service. A selection is presented in the Appendix of the EPA reference. This selection combined with ASHRAE ventilation Standard 62, provides the basis of measurement parameters used for this service.
There is still controversy as to what IAQ parameters provide a good measure for IAQ. This project does not attempt to address this issue in any form, but rather provides a flexible tool and data framework to express relevant IAQ information as new knowledge on IAQ emerges.

System Objective: The objective is to monitor IAQ conditions reliably and document system reliability including data transfer. The data transfer approach is similar to that of the remote efficiency monitoring system. In fact, it could be part of the same data file that is transferred from the local EMCS to the control center.

Structure of the IAQ Data Object Model: The IAQ data object model has two components: the IAQ model and the IAQProf. The IAQProf is a time series of the IAQ data object. The IAQ model represents the necessary information to characterize indoor air quality for one instance in time.

The data object model IAQ is structured such that substances are associated with a zone. The zone can be a thermal zone or an individual room. It could also be an outside air zone, because it may be important to monitor the concentration of air pollutants in the outside air. Each zone is assigned an array of concentrations of substances and a scalar for indoor dry-bulb temperature, relative humidity and outdoor air-flow rate into the zone. The outdoor air-flow rate is necessary to verify minimum ventilation requirements stipulated by ASHRAE Standard 62.

```
IAQ
|___ID
|___NumMx
|___Cmps[1..NumMx]
|___Zone[1..NumMx]
      |___OutID
      |___OutDoorIdent
      |___NumSub
      |___ChemNam[1..NumSub]
      |___CurCon[1..NumSub]
      |___CurTemp
      |___CurHum
      |___VolFlow
      |___MeasNorm
```

Figure 4-20: Tree Diagram of the IAQ Data Object Model

IAQ
IAQ data model.

ID
Identification of building for which IAQ data model applies.

NumMx
Number of zones. This includes indoor zones as well as outdoor zones. An outdoor zone is an arbitrary zone that specifies the air that is used for fresh air ventilation.

Zone[]
An array of components of the IAQ. Elements represent IAQ parameters for one zone.

OutID
Boolean flag. Set True if zone is an outdoor air zone. Set False if zone is indoor air zone.

OutDoorIdent
References an indoor zone to its associated outdoor air zone. The outdoor zone provides fresh air to the indoor zone.

NumSub
Number of substances to be monitored.

CurNam[]
Array of substance names.

CurCon[]
Array of concentrations of substances.

CurTemp
Current zone dry-bulb temperature in [ºC].

CurHum
Current relative humidity in zone .

VolFlow
Measurement of volume flow of outside air.

MeasNorm
Measurement to normalize the VolFlow. This datum is used to test minimum ventilation requirements expressed in, for instance, [cfm/person]. In this example MeasNorm would be assigned the number of occupants designated to the zone.

Time Sequence Diagram: Assume the IAQ information is stored in the FMS. The IAQ values are averaged over one hour and stored for each hour. Each day the service provider requests 24 hourly IAQ data of the previous day. Assuming the number of designated occupants for each zone is constant, the FMS needs to send only the concentration and ventilation values back to the service provider.

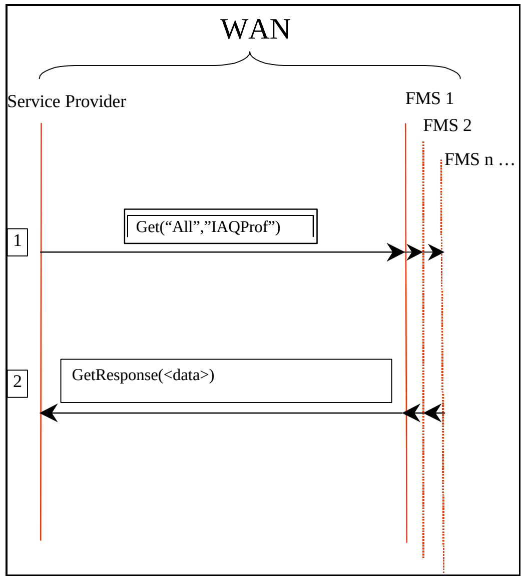

Figure 4-21: Time Sequence Diagram For IAQ Monitoring Services

Table 4-10: Description of Sequence of Messaging for IAQ Monitoring Service

IAQ monitoring time sequence diagram actors	
Actor	**Description of Actor**
Service provider	Utility, ESCO, maintenance comp.
FMS 1, 2, 3	Facility management system in facility 1, 2, 3

Requested IAQ data	
Message ID and description	**Message Detail**
Service provider requests the IAQ time series from FMS	Get("All", "IAQProf")
Each FMS returns requested data	GetResponse(<data>")

Nature of Data Transfer: Same as for the remote efficiency monitoring application.
Bandwidth Requirements: Same as for the remote efficiency monitoring application.

4.12 Dynamic Demand Bidding (DDB) to a Power Exchange

Customers with some degree of load flexibility may become market participants by bidding into a power exchange (PX) the dispatchable load for each trading interval of the trading day, and the associated prices they are prepared to receive for dispatching their demand for each bidding period. The DDB service automates the bidding process and generates control strategies after the market clearing prices have been received to meet the load targets as bid into the PX.

The customer bids directly into the PX or through a load aggregator (LA), who as an agent for many individual customers, aggregates individual bids for submission to the PX. The DDB service discussed herein is based on the new Californian power market structure that has been in operation since March 31, 1998. A brief overview of the bidding process at the California PX is given in the following section.

Bidding Process to Determine Market Prices of Electric Power in California

One of the new entities in the California power market is the PX, whose primary purpose is to provide an efficient and competitive electric energy auction open to all suppliers of electricity for the purchase of power at market prices. The PX will accept demand and generation bids from its participants and determine the market clearing price (MCP) at which energy is bought and sold. The MCP is determined by the intersection of the aggregated system-wide demand and supply curves (see Figure 4-22). The balanced demand and supply schedules at MCP for the successful bidders are then submitted to the independent system operator (ISO) for review of transmission line congestion. In cases where transmission congestion occurs, the ISO determines incremental adjustments based on bidders' adjustment bids to resolve congestion. This adjustment is considered the second iteration of the bidding process.

The PX has two bidding markets: (1) a day-ahead-market, and (2) the day-of-market. The MCP is determined for both markets using the same method. The PX communicates price and trades quantities electronically to PX participants immediately after the market is closed.

Participants of the bidding process can be:

- utility distribution companies (UDCs)
- retailers, energy service providers, load aggregators
- large customers desiring direct access to transmission lines
- power marketers
- generators.

Of interest for the definition of the DDB service are bidding requirements that pertain to UDCs, retailers, energy service providers (ESPs), and load aggregators. These participants bid a demand schedule to the PX. A demand schedule defines the elasticity of electric demand with respect to price. As such, it characterizes the ability of end-users to reduce loads at increasing electricity prices. The UDCs, ESPs, and LAs bid a demand schedule that represents the sum of all of their individual customers.

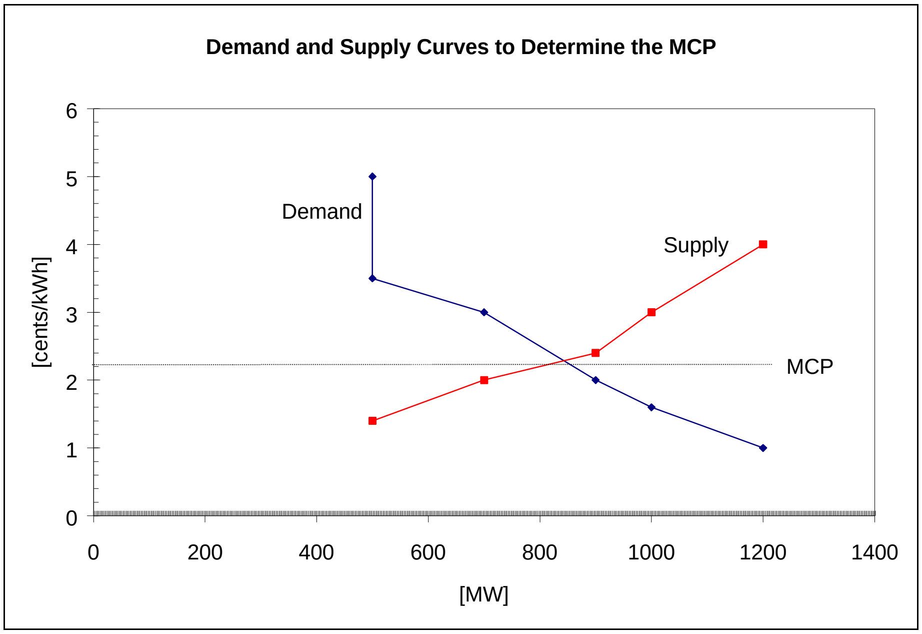

Figure 4-22: Hypothetical Demand and Supply Curves. Intersection Determines the Market Clearing Price (MCP)

Each purchaser of wholesale electricity traded at the PX provides a demand schedule, which will be aggregated by the PX to one curve representing the entire system demand.

In a dynamic market in which customers may frequently change their ESP (similar to long distance telephone services), it may be difficult for an ESP to determine an aggregated demand curve. The DDB service adopts a bottom-up approach that places the responsibility of determining the price-elasticity in the hand of each customer who knows best what loads can be shed under any given circumstances. The bottom-up approach provides robustness in a constantly changing environment. It is very likely that the price-elasticity may change on a daily/weekly/monthly basis as the building's occupancy or the facility's process planning schedules change. The transfer of each customer's demand curve is proposed to be automated via the communication link between the customer and the ESP.

Service objective: The DDB service is defined as a contractual agreement between two entities; an individual customer and a power exchange or, alternatively, between a customer and a LA or ESP. As such, the service enables the individual end-user to bid his dispatchable load directly into the power exchange or transmit the individual bid to a LA who, in turn, will forward to the power exchange the bid aggregated with other bids.

After the MCP is determined, the PX transmits each participant's load or generation commitment (preferred schedule) that is at or below the MCP. The preferred schedule, unless revised by the ISO, constitutes a purchase contract for the sale of a specified quantity at a specified price. If the real-time load deviates from the specified quantity (which is almost always the case), a supplemental bidding schedule will be used in the settlement process. To avoid higher market prices or even penalties for exceeding the specified demand quantity, load management strategies must be employed to limit the load to the target demand quantity.

System Objective: The system that enables the DDB service transmits individual customer's demand schedules from the facility management system to a receiving central server. This server could be operated by the PX or an LA. The server validates the received information and combines the individual demand schedules to one aggregated schedule that satisfies the data format prescribed by the PX.[7] The validation test will verify completeness of the data set according to the specified format and return a message to the sender in cases of non-compliance with the format requirements. The system interfaces with both the PX's communication technology for the bidding process, as well as with the facility management system for receiving the MCP from the PX. The service would invoke load management services as described in previous sections.

Nature of Data Transfer: The DDB service requires two-way communication because of the bi-directional data transfer. The communication scheduling is determined by the central server. The central server issues requests for the submission of customer demand schedules. The EMCS responds to the request.

Bandwidth Requirements: The customer demand schedules are limited to a finite number of quantity-price pairs that represent the price-elasticity. For the California PX, the limit is 16 price-quantity pairs[8]. A quantity-price pair consists of an electric demand [MW] and an associated price [$/MWh]. The data size is small. Depending on the necessity of bidding iterations, the DDB service may be invoked once or several times within a one hour period.

Because of the stringent timing requirements imposed by the PX, timeliness of the communication may pose relatively high bandwidth requirements for establishing the DDB service.

Data Security Issues: The price elasticity of individual customers is considered proprietary. This information is only to be disclosed to the intended receivers.

Time Sequence Diagram:

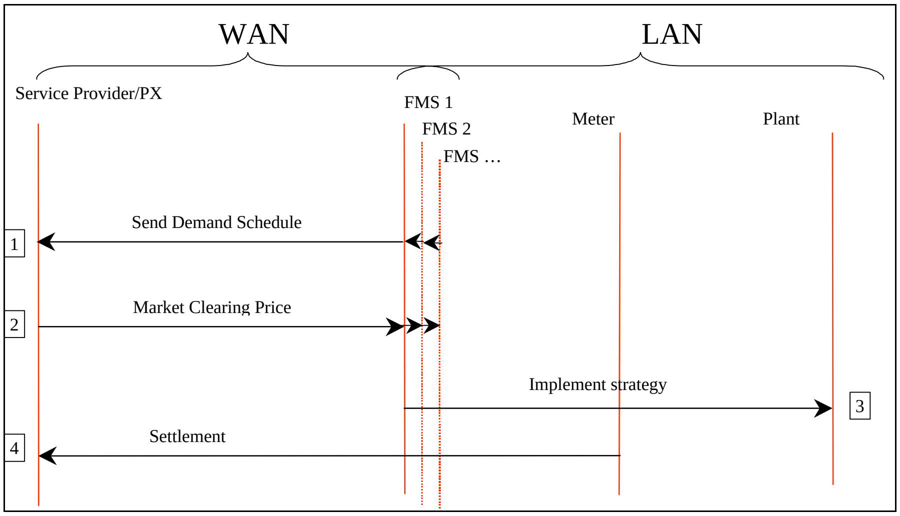

Figure 4-23: Time Sequence Diagram For Dynamic Demand Bidding

[7] Since the regulatory framework for a competitive electric power market is most mature in California, it is proposed to utilize the regulations pertaining to the California Power Exchange. In particular, the information regarding procedural protocols for PX bidding, bid evaluation, and scheduling and control documented in the PX tariff [PBEP, 1997]; [PSCP, 1997].

[8] Section 2.4.1 of Power Exchange Bidding and Bid Evaluation Protocol, California Power Exchange, 1997, sets a limit of 16 quantity-price pairs. For establishing the DDB service, this may not necessarily be a limit; however, it indicates the overall magnitude of quantity-price pairs [PBEP, 1997].

Table 4-11: Description of Time Sequence Diagram For Dynamic Demand Bidding

Power quality time sequence diagram actors	
Actor	**Description of Actor**
Service provider	Power exchange
FMS 1, 2, 3, Meter Plant	Facility management system 1, 2, 3 Metering device HVAC heating and cooling plant

Sending power demand bid and receiving MCP	
Message ID and description	**Message detail**
1. FMSs sends demand schedule consisting of demand/price pairs to service provider/PX	ID number or customer classes Date/time Demand/price pairs (1…n) end date and time
2. Service provider/PX evaluates bids and determines MCP. Service provider/PC sends back MCP to FMSs	ID number or customer classes Date/time MCP for each hour
3. Based on MCP, FMS evaluates load control strategies and sends directives to selected plants/processes	Equipment ID Load management strategies - turn off - modulate
4. Meter sends consumption to service provider for settlement	ID number or customer classes Timestamp of transmission date and time consumption

5 Application Data Modeling and Protocol Mapping

This section first discusses application data modeling in general and how communications standards have evolved to address perceived requirements.

A rationale is presented for the use of a common data model for the services developed in this document. This common data model would then be translated into specific protocols for use. BACnet, LONTalk, and CEBus are briefly analyzed as to how their composition relates to the data modeling used in this report.

Following this discussion is a presentation of UCA's Common Application Services Model, CASM, and how it can be applied as a "mother tongue" for data modeling in applications development.

Finally, it is shown how the elements of actual models that are described using CASM can be translated or directly represented in BACnet, LONTalk, and CEBus. Proposed extensions to the BACnet object model are presented to facilitate this mapping.

5.1 Evolution of Communications Standards

The primary goal of communications standards is interoperability. That is, the ability of an application on one computing platform to interact with or use information available on another computing platform. Historically, this was accomplished by agreeing on the physical connection means and various layers of the “OSI reference model.” Applications were somewhat homogeneous in that information typically did not leave the domain of a single enterprise or single group of collaborators. Once applications grew beyond the scope of such a small group, it became necessary for devices to be built independently. They were then connected together for collaboration by entities that were not involved in the creation of the devices or the communications means. This scenario gave birth to many of the communications standards that were evolved primarily in the 1970s and 1980s. However, the applications were still homogeneous. There would be a network for SCADA (supervisory control and data acquisition), another network for office applications, etc.… Because of this “topology” of communications, many specialized communications protocols were developed for different application domains. In fact, it could be observed that in the 1990s, virtually every technical domain was represented by its own communications standards effort.

The result was a cornucopia of standards that were “domain-specific.” That is, the communications standards, besides providing for the generic goal of exchanging information, contained a lot of semantics and architectural elements that recognized specific industry requirements. An example of this is DNP, which recognized the “freezing” of data measurements in its communications services model. The advent of WAN connections to LANs introduced a new obstacle to interoperability. That is, the scope of applications evolved to overlap domains. For example, in communicating with customer-site-based electric meters, the following application areas might need to interact with the meter – and this is all with a single device:

- meter reading
- communications network management
- energy service provider billing application
- power quality network management and fault detection.

It should be noted that once the cost of deploying a communications means has been absorbed, the use of the network for applications beyond a single device is a valuable extension of resources. Thus results the current and future situation of a highly interconnected network of equipment and applications.

Because of this interconnectivity of historic “islands of communications”, many interconnected standards will coexist on the same network. This can be considered using an analogy of having several simultaneous private meetings moved from a set of private offices to a gymnasium. The resulting cacophony of conversations might now need to be coordinated so that they can be heard clearly. Further, the gymnasium would have to agree on some common “protocol” to allow groups to speak their turn. Finally, because some of the meetings might need to share information with others, some common vocabulary would be necessary so that the different groups could successfully communicate. For example, doctors and lawyers with different vocabularies often do have to collaborate.

This sounds a great deal like the rationale for communications standards to begin with. The point is that this process of collecting common requirements and developing common semantics must begin again as a result of the interconnection of networks.

5.2 Coalescence

The previous section described the need for the coalescence of communications standards. This section will summarize a set of communications standards used for SCADA and describe the driving forces that will eventually reduce the number.

The following figure illustrates the relative complexity (and therefore implicitly, cost) versus the capability of several application layers in communications protocols. The protocols shown in the figure are all suitable for interoperable exchange of measurement and control information such as a switch position – i.e. On/Off. The relative positions of specific standards shown are not important and are only approximate. Each standard is positioned as a range of complexity versus capability indicated by the narrow ellipses. The larger ellipses illustrate potential regions of coalescence.

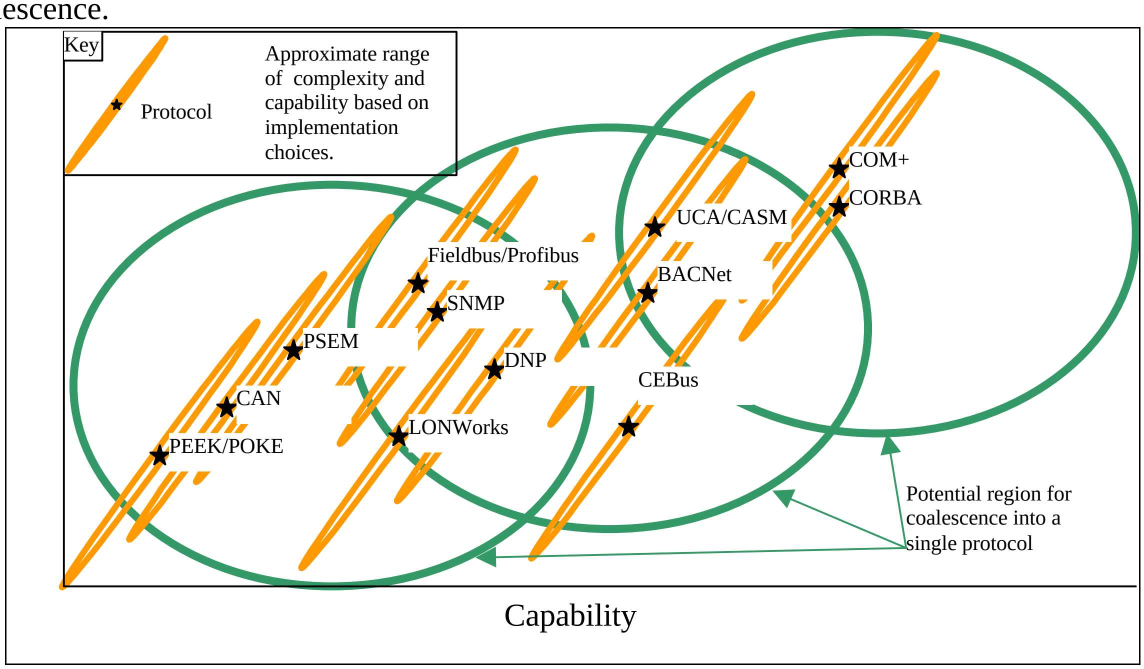

Figure 5-1: Complexity vs. Capability in Communications Standards

Key:

BACnet	ANSI/ASHRAE 135 protocol for Building Automation and Control Networks
CAN	Control Automation Network
CEBus	Electronic Industry Associations Consumer Electronic Bus, EIA 600
COM+	Microsoft Distributed Object Model
CORBA	Object Management Group Distributed Object Model
DNP	Distributed Network Protocol
Fieldbus/Profibus	Industrial control network
LONWorks	Echelon's Local Operating Node communications protocol
PEEK/POKE	Metaphor for "Basic programming language" memory manipulation instructions
PSEM	Protocol for Electric Meters, ANSI C12.18, ANSI C12.19
SNMP	Internet Engineering Task Force's Simple Network Management Protocol RFC 1156/ RFC1157
UCA/CASM	EPRI Utilities Communication Architecture Common Application Services

In order for a standard to become widespread, it presumably must achieve economies-of-scale that reduce the cost of deployment and operation of the network. Each standard requires support from semiconductor manufacturers, software developers, and application engineers. A common set of capabilities must therefore be divided among the standards in practice. The standards listed all perform a similar service – exchange of SCADA information. It is therefore likely that as application domains overlap, application engineers will continually make selections of which standard to use for the communications of a given type of information or with a particular device.

5.3 How to Coalesce Disparate Standards

Any one standard is not likely to meet the needs of all current and future applications. It is therefore the premise of this analysis that one or more points of complexity versus capability will emerge as coalescence points where a single standard will emerge. Since any deployed technology has vested interests and costs associated with change, these coalescence points will only emerge and firm up over time (years) as manufacturers of devices and communications equipment make repeated choices. The need for a new protocol stack has traditionally come from two needs:

- industry-specific language and performance requirements
- technical standards groups working on related problems in isolation.

Consequently, the large selection of communications standards reviewed has some common elements and then some domain-specific ones. The common elements arise from the simple need to exchange data such as measurements, set-points, configuration information, etc. The industry-specific elements derive from varying performance requirements and cost drivers that were specific to the domain of the developers. In each case, the standards developers, in essence, chose an optimal point on the complexity versus capability graph and developed their standard.

Coalescence between two standards can occur through transformations of:

- physical and logical transports used
- application models used.

In applying one standard to support the requirements of a second standard, mappings must be made that allow requirements not supported directly to be achieved.

Performance requirement differences can be transformed by adding bandwidth and physical layer redundancy to meet performance needs. For example, 10/100BaseT Ethernet has become extremely cost effective because of the economies-of-scale. As a result, it is penetrating into applications for which it was not originally considered suitable. Limits in the determinacy and reliability of transport have been addressed through adding more speed and redundant cabling.

Complex methods (services) can transform to simple methods with complex arguments. For example a PSEM method, which reads a meter table, has the approximate semantics:

ReadTable (id)
ReadTableOffset (id, offset, count)
ReadTable1Index (id, index, count)
ReadTable2Index (id, index1, index2, count)
…

These "Table" specific services can change to:

Read (tableID)
Read (tableID [offset], count)
Read (tableID.index1, count)
Read (tableID.index1.index2, count)

As shown, a generic Read service has replaced the domain-specific services of ReadTable, ReadTableOffset, ReadTable1Index, and ReadTable2Index, with no loss of specificity.

5.4 Modeling Services Over Heterogeneous Networks

To implement services that involve devices in multiple domains, a common model of the service must be devised. The common model can then be piece-wise translated into the local *tongue* of each device or entity that must collaborate in communications implementing the service.

To accomplish this task requires two steps:

1. Implement the services in a protocol-neutral generic form.
2. Map the neutral generic form to each local protocol that must carry the messages of the service.

The protocol-neutral form must embody a model of devices and communications entities that can be straightforwardly translated into the various local protocols of interest. It should also be rich in architectural elements that will facilitate implementation of the messaging in an efficient manner. These architectural elements should embody at least the following requirements:

- Ability to exchange information without intimate detailed knowledge of individual devices and entities in communications. It should be possible to interact with common information in a common way independent of the specific identity of an instance of a device. In other words, it should not be necessary to know everything about a device before it is possible to know anything – i.e., complete read of configuration to locate specific features already known to be present.

- Ability to recognize the dual nature of devices – topology-independent modeling of functionality, and, topology-specific network management and configuration management. Topology independence means that an application needs to know“who” a device is and “what” a device is, but does not need to know “where” a device is to construct a proper message. Clearly network management needs to know about "where" and has the responsibility of ensuring the availability of the topology-independent view.

- Provide a robust yet constrained set of generic services that will be easy to translate into local protocols.
- Facilitate role-based access to information so that private information can be shielded from those entities unauthorized to view all information, while authorized to interact with some information.

5.5 Data Modeling and Hierarchy Options

Once a robust set of service models is created, they must be mapped to the different local protocols that may already be implemented. Domain-specific protocols have chosen different methods to represent the data models of devices. To develop a sense of the different approaches taken by home and building automation protocols, a figure is presented below. It shows a generic and progressive complexity of information (termed hierarchy granularity in the figure). On the side, it is shown how the architectural elements of the standards map into this hierarchy.
The following figure illustrates the continuum of possibilities and choices made by UCA, BACnet, CEBus, and LONTalk.

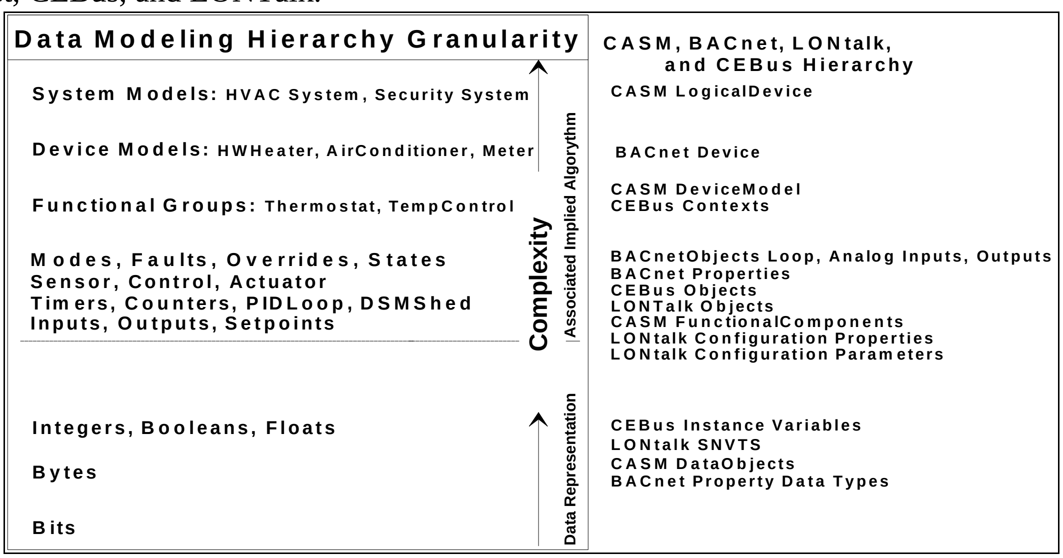

Figure 5-2: Data Modeling Hierarchy Granularity

Where:

Bits:	The smallest atomic components of information.
Bytes:	Grouping of bits that represent parts of primitive data types.
Integers, Booleans, Floats:	Primitive data types used to represent useful information.

Modes, Faults, Overrides, States, Sensors, Control, Actuator, Timers, Counters, PIDLoops, DSMShed, Inputs, Outputs,Set-points:

Groupings of primitive data types that have associated algorithms. They are low level objects.

Functional groups:	Collections of simpler objects that collaborate to provide basic recognizable components of devices such as a temperature control.

Device models: Sets of Functional groups that together comprise models of real devices.

System models: Sets of Device models and their components that perform some collaborative system function such as an HVAC system.

The concept of navigating seems a reasonable way to get to a specific component of the hierarchy. For example, because it is known that an HVAC system has a thermostat, and a thermostat has a temperature sensor, and a temperature sensor has a value, therefore, if one can locate the specific HVAC system, we can communicate with the:

HVACSystem.Thermostat.TemperatureSensor.Value.

With this logical representation of information structure, a set of building blocks can be envisioned that would be "topology-independent." Another example might be the transmission of a real-time price (used in distributed load management applications). Using this hierarchical addressing notion, it would be possible to devise a single message that represented the real-time price that could be understood by all devices to which it is transmitted without further translation. This topology independent messaging is a key goal of the modeling approach.

As seen in Figure 5-2, the various protocols have made different choices of the depth of modeling to standardize. LONTalk is the most primitive in that it represents only primitive data types and does not have definitions for information of higher aggregation. Through its LONMark interoperability effort, however, some of the higher aggregations are defined. But these are conventions and not actually part of the information content of messaging.

BACnet's object model is aggregated to a higher degree than LONTalk. While LONTalk stops at primitive SNVTs, which are principally primitive data types that can be read, written, and announced, BACnet objects are structures of BACnet properties that together represent re-useable primitive groupings.

BACnet and LONTalk model devices primarily as collections of primitive objects rather than as hierarchical arrangements of data representing whole device functions; LONTalk as mainly primitive types, and, BACnet as fixed depth structures. There are relatively few primitives and their application in the field is not regulated by the standard. For example there is not currently a model of a thermostat that specifies a temperature measurement and that its data are represented as a floating point number. Consequently, there is no guarantee that all such temperature measurements in thermostats, independent of manufacturer, will be the same data type, thus requiring the same translation. LONTalk is similar and has even less structured primitives than BACnet.

Both BACnet and LONTalk are highly topology dependent in that objects are located through an installation specific enumeration. This necessitates a specific mapping of messages separately for each installation. Later in this section, proposed enhancements to the BACnet object model are presented to address topology independence.

On the other hand, CEBus specifically defines models of these higher level functions. With CEBus, the functional groupings are specifically represented in the protocol. These contexts permit messages to be addressed to "thermostats" without knowing specific addressing information of how and where the thermostat is located.

5.6 CASM, as a Mother Tongue

To illustrate the challenge of achieving interoperable messaging, consider this scenario:

> A new energy service provider desires to offer a new real-time pricing service to its million customers. The customers each own and operate HVAC controls that are to receive and act on a distributed real-time price. The HVAC controls were manufactured by 36 vendors and installed and maintained by several thousand contractors to provide basic energy control to the individual facilities. The service provider doesn't own or have any direct control or responsibility of the configuration and maintenance of the HVAC controls.

How can this service be implemented and reliably operate when the service provider has no direct control over the configuration and maintenance of the end control device? What happens when the customer's controls contractor reconfigures the control system and network?

The Common Application Services Model provides key features for the representation of devices and device characteristics that are essential for a large-scale deployment of services as described in the scenario above. Although similar to BACnet in many respects, CASM specifically supports a topology-independent message construction. In addition, CASM provides a method for describing models of specific device and application functions beyond simple data types. CASM supports relatively unconstrained hierarchical modeling, which facilitates the logical organization of models. Finally, CASM allows for the conveyance of the semantics of a message in the message. This allows a message, such as a real-time price, to be automatically understood by supporting recipients of the message without prior coordination or configuration.

These features of CASM are essential to the cost-effective deployment of new services to millions of customers, because it provides the mechanisms for a single message to be constructed in a way that can be universally understood. Consider again the scenario above. If BACnet alone were used, a real-time price message would have to be constructed that was unique for each BACnet node to which communications need occur. This is because BACnet objects are addressed through a simple enumeration (0, 1…) that is unique to each instance (that is, each individual BACnet device).

Additionally, the ability of CASM to support relatively sparsely populated universal models allows devices of varying complexity to share common features. For example, there are many different kinds of electrical meters – from simple residential meters to those that provide complex power quality measurements. However, they all measure power consumption as the core feature. Therefore, the representation of power consumption data should be the same for all meters regardless of the breadth of features they offer.

As models based on these principles become detailed and rich in features, the need for hierarchical organization becomes stronger. Hierarchical organization facilitates object name resolution and avoids conflicts in object naming.

While it has been argued that a universal and hierarchical addressing model is more complex than the simple enumeration approach, research has shown that the additional complexity of parsing a hierarchy requires 200-300 bytes on an 8-bit microcontroller[9].

CASM was designed to model devices in a protocol-independent way. Yet, it was designed with a minimal set of requirements for messaging transport to facilitate its mapping to protocols such as BACnet and others. In this regard, CASM can be considered a meta-model that facilitates mapping into other protocols so that applications over networks utilizing heterogeneous protocols can interoperate. This report proposes extensions to BACnet (discussed in Section

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[9] Presented to members of TC57 Working Group 9 of the IEC, December 1998.

5.7.1) so that the notions of CASM can be directly transported by BACnet. CASM is being used as the generic object model to represent the data models used in services proposed in this report.

The requirements addressed by CASM are divided into two parts – those relating to the functional capabilities of the model, and, those relating to object modeling requirements. What follows is a brief summary of these requirements. The reader is referred to the UCA 2 documents [UCA 2.0, 1997] to obtain greater detail and rationale.

The following functional requirements are specifically addressed by CASM (only a subset are presented in this document):

• Reading/Writing Remote Data	This is the principal activity in interacting with remote devices to determine or affect changes in state.
• Device Control Commands	Provide controlled access to devices for certain critical operations.
• Event Reporting	Report by exception of significant occurrences detected by a remote device and spontaneously notifying one or more clients, accordingly.
• Journaling	Recording of time stamped historical observations.
• Security	A uniform means of controlled access to devices based on the asserted and authenticated role of the client.
• Time Synchronization	A means of accurately distributing time so that time-stamps of separate devices can be accurately correlated.
• Management of Remote Devices	Configuration management and mode selections.
• Network Management	Maintenance of the network accessible health of the remote device.
• Gateway and Adapter Management	Management of devices that might be on various LANs on the other side of a gateway.

The following are the object modeling requirements specifically addressed by CASM:

• Topology and Protocol Independent	An application (other than network management) should be able to interact with a device using a logical reference and then independent of the communications means to reach the device.
• Multicast / Query Support	Ability to direct multicast and conditional messaging to one or more remote devices.
• Standardized Data Types, Scales, Units	Unambiguous transfer of common information without having to read specific device configuration information.

- Encryption, Authentication, Secure Views — A uniform means of using security parameters within the application process.
- Interoperability and Extensibility — An unambiguous way of expressing common messages without tailoring of the message to specific instances. Extensibility must be built in to assure that manufacturers are encouraged to enrich standard models.
- Self Description, Inheritance, Aggregation, Polymorphism — Standard object oriented principles that enable robust distributed objects to be created and evolved.
- No Need to Tailor Message for Each Instance — A message to an object must be understandable without prior communications with a specific instance to detect differences in configuration.
- Client and Server Comparable Complexity — It was desired to enable the development of services based on the creation of very small servers as well as small clients.

5.6.1 Introduction to Object Modeling

Object oriented terminology used in this introductory section includes: class, object, method, attribute, inherit, instantiate, and aggregate. They are briefly described:

- *A class is a template for the creation of objects.* Classes abstractly define attributes (data) and methods (services) used to perform some related function. A class can be considered an agreed upon description of some commonly observable thing or process. *Attributes* represent the state information described by a class. They can be considered the things that a class has. The *methods* of a class define the operations that the class supports, i.e., what a user can do with it.
- *Classes can inherit from one or more classes* by taking on the attributes and methods (and hence the functionality) of the class(es) it inherits from. This inheritance may include generalization and specialization, in which the abstract attributes and methods are enhanced, restricted, or extended by some further definition. An inheritance hierarchy can be defined in which simple classes can be refined into more and more complex classes. An inheritance hierarchy is often presented as a picture of an inverted tree with the branches representing the path of inheritance from ancestor to descendant and the leaves representing the classes in the hierarchy.
- *Classes may also aggregate other classes*. This means that one class, the child, is contained in another class, the parent. The properties of the child can be accessed through the parent by navigating down the containment, or aggregation, hierarchy. For this reason, aggregation provides another kind of inheritance in that the parent can be considered to have the attributes and methods of the classes that are contained. An aggregation hierarchy is often presented like a file system on a PC where at each level of containment there are files (primitive classes) or folders (parent classes aggregating more child classes).
- *An object is an instance of a class.* The process of "instantiation" is the creation of an object from its class. Each instance has a unique identity. For example, an RTU is a well-known class of utility device. If I purchase one, I have an instance, or object, of the class, RTU. Its

unique identity might be “R1234”, a reference number used by the owner to identify it among all the other devices it owns and operates. While all RTUs may be similar, there is one, and only one instance “R1234.”

5.6.2 Introduction to CASM Object Classes

Device models based on CASM represent the behavior of real devices by defining standard classes and objects (instances of classes) built up through inheritance and aggregation from the basic CASM class definitions. Users of CASM-based devices can access the device features through well defined network services operating on the objects. The CASM Data Access Model establishes the rules for defining and organizing the object models. These objects can then be used in communications.

In CASM, objects that are directly accessible by a client through a network are contained in an object from the **Server** class. The **Server**s, and the object instances that they contain, are mapped to the UCA communications protocols through the procedures defined in this document.

Objects within a **Server** inherit from the CASM classes **LogicalDevice, DataObject,** and **DataSet,** described in this section. In addition, three special classes that inherit from **DataObject** are **DeviceIdentity,** which contains nameplate information; **DeviceModel,** which is the representation of the complete device function; and, **FC**, FunctionalComponent, which groups common components of device functionality into an easy to use form inside a **DeviceModel**.

A LogicalDevice in CASM represents the capabilities of a real device. As in real devices, LogicalDevices are a composite of the following parts: an enclosure, a nameplate, and one or more subassemblies that together provide the functionality of the complete device. For example, a distribution relay device might include several standardized relay functions. In addition, an electronic distribution relay would likely have a capability to measure the voltages and currents in the conductors it is controlling. To represent this device in CASM, a LogicalDevice would be created that contained a nameplate, DeviceIdentity, a measurement unit DeviceModel, and one or more standardized relay function DeviceModels.

It should be noted that CASM allows for arbitrary assembly of DeviceModels into LogicalDevices. The composition of a LogicalDevice is left to the manufacturer and can always be determined from an instance of an LogicalDevice via the communications services of CASM.

The following is a conceptual model of the Communications Server as represented by CASM:

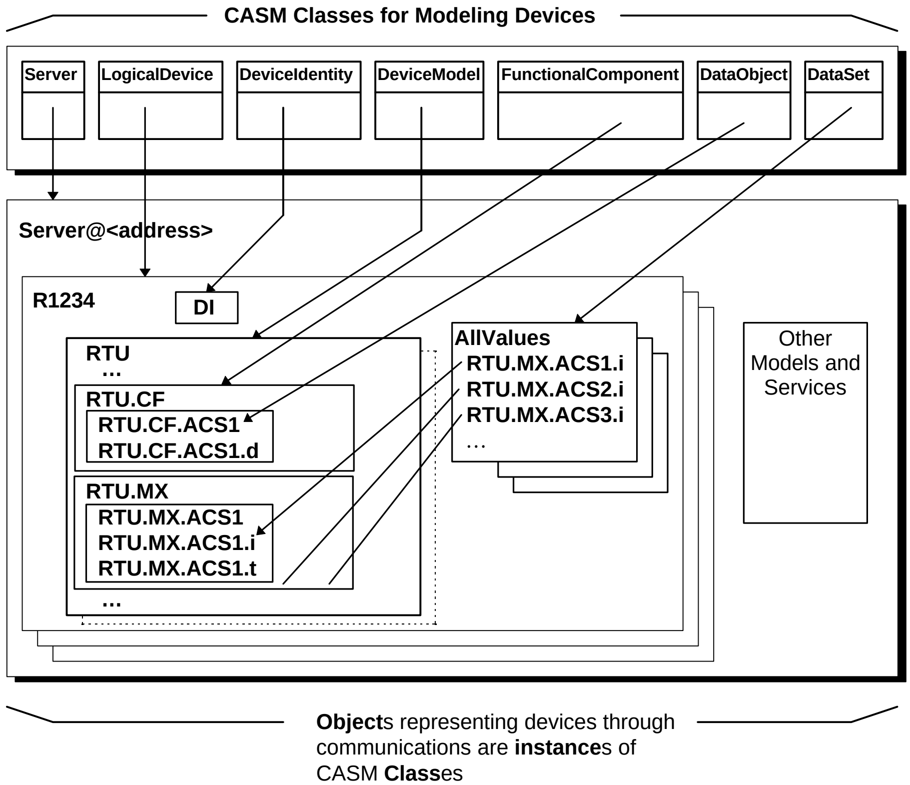

Figure 5-3: CASM Device Modeling Classes and Their Relationship to Objects

As shown in the figure above, the Server consists of one or more LogicalDevices, LD (e.g., R1234). Each LogicalDevice contains one DeviceIdentity, DI, one (typically) or more DeviceModels, DM (e.g., RTU) , and zero or more DataSets, DS (e.g., AllValues).
Each DeviceModel contains a set of FunctionalComponents, FCs (e.g., RTU.CF, RTU.MX), which in turn contain sets of simpler DataObjects, DO, (RTU.MX.ACS1, …), which represent the behavior of the modeled device.
The use of LD, DO, DM, DI, FC, and DS as abbreviations for the longer names simplifies tables and will be used interchangeably from this point forward.
The DMs are described in other UCA device modeling documents and are templates for making objects that represent the device functionality. In this regard, the RTU DeviceModel is not an RTU, but is the template for an RTU. To make an object of the model, one needs to instantiate it. The act of instantiating an RTU is like building an RTU from a set of blueprints. The RTU Object is created according to the specifications of the RTU DeviceModel template and is placed in a virtual version of an electronic device, a LogicalDevice. However, just like placing a single board computer in an electrical enclosure to mount it to facilitate its use, an RTU object is placed in a container to facilitate its use for communications purposes. The container for the RTU object (and any other DeviceModel instance) is a LogicalDevice. Similar to the enclosure that houses the circuit board, the LogicalDevice does not externally reveal much about the nature of what's inside. It is only by using or browsing what's inside that makes the "functionality" of the assembly apparent.
As with most electronic enclosures, LogicalDevices have a nameplate that lists make/model/serial number and other related information. Typically nameplates deal with

information that is independent of the purpose of the device. The nameplate class for CASM is the DeviceIdentity, DI.

Therefore, the LogicalDevice contains a nameplate and some functionality. In CASM the nameplate is an **instance** of the DI class, and, the functionality is an **instance** of one or more DMs.

Finally, DataSets, DS, represents lists of references to DO's that can be accessed by a single name in communications. The principal advantage is that, for these common groupings, a simple short message can request a substantial amount of selected information.

Therefore, to summarize the classes that CASM provides to use in modeling utility devices:

- **LogicalDevice**s, LD, are containers for objects representing device functionality, DeviceModels, and nameplate, DI. In addition, LogicalDevices contain convenient lists of frequently accessed or referred to information, DataSets.
- **DataObject**s, DO, are used to represent the specific elements of functionality of the device. These DataObjects may be hierarchical and may be nested in any number of levels.
- **DataType** describes the composition of a DataObject's "value" attribute. Interoperability of devices using CASM basically comes from agreed upon DataObject names and DataType.
- **DeviceModel**s, DM, are used to represent the idealized functional models of real devices. DeviceModels inherit the properties of DataObjects. DeviceModels are assembled from a reusable set of FunctionalComponents.
- **DI** is the DeviceIdentity DataObject. The DI contains the information that is commonly found on a nameplate found on most equipment. The components of DI represent a guaranteed minimum set of interoperable information available from all CASM compatible devices independent of device purpose.
- **FunctionalComponent**s, FC, are structured DataObjects that acts as a framework to group common features of a device and are the major components of a DeviceModel. A FunctionalComponent organizes information by purpose such as measurements (MX), configuration information (CF), status inputs (ST), or descriptions (DC) to name a few.[10]
- **DataSet**s, DS are used to group commonly used DataObjects for easy retrieval. A LogicalDevice can have zero or more DataSets. DataSets are flat (non-hierarchical) ordered lists of references to DataObjects (DOReferences).

5.6.3 CASM DataObject Services

CASM DataObject services are similar to those available for reading and writing BACnet object properties. They are summarized below:

GetDataObjectValues: A client uses this service to retrieve the values of one or more DataObjects from the Server.

SetDataObjectValues: A client uses this service to set the values of one or more DataObjects being made available by the Server.

SetDataObjectValues(Unconfirmed): A client uses this service to set the values of one or more DataObjects being made available by the Server. No response is given to this request.

[10] By analogy to applications on PCs, if a DeviceModel can be considered a "dialog window" representing some functionality of an application, FCs can be considered "pull down menus" grouping common sub-functions available in the window – in this case common groupings of sub-function within the DeviceModel.

GetDataObjectAttributes:	A client uses this service to obtain the Type Description attribute of a specified DataObject being made available by the Server.
CreateDataObject:	A client uses this service to create a DataObject.
DeleteDataObject:	A client uses this service to delete a DataObject. The Delete DataObject service shall return a result indicating FAILURE if the service is applied to a DataObject that has a Deletable attribute with a value of FALSE.

5.6.4 Standard CASM Data Types

The following table contains the standard abstract data types defined in the CASM models. DataTypes may be simple or complex. Complex DataTypes describe the value of DataObjects that aggregate or contain subordinate DataObjects such as arrays or structures. The data types used in the UCA models are listed in the table below.

Table 5-1: CASM Standard Data Types

UCA Standard Data Type Name	Description, Range of Values (where applicable)
BOOL	Boolean - 1 bit, True (1) or False (0)
BSTR2	Bitstring - 2 bits
BSTR8	Bitstring - 8 bits
BSTR16	Bitstring - 16 bits
BSTR32	Bitstring - 32 bits
BSTRn	Bitstring - variable number of bits
INT8U	Unsigned Integer - 8 bits, 0 to 255
INT16U	Unsigned Integer - 16 bits, 0 to 65,535
INT32U	Unsigned Integer - 32 bits, 0 to 4,294,967,295
INT8S	Signed Integer - 8 bits, -128 to +127
INT16S	Signed Integer - 16 bits, -32,768 to + 32,767
INT32S	Signed Integer - 32 bits, -2,147,483,648 to +2,147,483,647
FLT32	Floating Point, IEEE format, single precision
FLT64	Floating Point, IEEE format, double precision
VSTR8	printable ASCII text string - 8 characters
VSTR16	printable ASCII text string - 16 characters
VSTR32	printable ASCII text string - 32 characters
VSTRn	printable ASCII text string - 1 to n characters
VSTR	null terminated, printable ASCII text
OSTRn	Octet String - 1 to n length
BTIME4	number of ms since midnight - 4 Octets (GMT)
BTIME6	number of ms since midnight and days since 1 January 1984 - 6 Octets (GMT)
ENUM8	Enumerated value, 8 bits, signed – Well known values positive, 0 always reserved and unused
ENUM16	Enumerated value, 16 bits, signed – Well known values positive, 0 always reserved and unused
IDENT	A printable ASCII text string representation of a DOReference – identifies a DataObject or subcomponent of a DataObject within the scope of the Server
STRUCT	Structure
ARRAY	<TYPE>[I][j][k] ..ARRAY elements for three dimensions of TYPE
BLOB	A reference to a binary large object that can be transported in pieces rather than a single messaging transaction.

(Note: The UCA Standard Data Type Name shown should always be presented in upper case)

5.6.5 DataObject Naming Conventions

While the correct operation of the CASM services does not depend on strict naming conventions, the following guidelines are recommended when defining DeviceModels for use with CASM:

- Each standardized name should be written using upper-lower case boundaries as opposed to spaces or underscores. The elimination of spaces preserves the ability to use the names directly in programming. The use of upper/lower case boundaries instead of underscores reduces the number of bytes on the wire by one for each use. Concise nomenclature is desired because some transport mappings will use the names in the message and this effects bandwidth.
- Each standardized name can be used only once – independent of the position the name may have in an aggregation / hierarchy / structure. This preserves the future possibility of canonical addressing which substitutes unique numbers for names in allowing for lossless compression of named binding and thus bytes on the wire. This means that the same name, wherever it is used in a DataObjects structure, must always represent the same thing. This means that "V" cannot be voltage in some uses and vapor pressure in others. It is useful to have, however, "MX.V" and "CF.V." In this case V appears in different DataObjects, but still represents the same classification of information. In fact it serves to associate two related but independent pieces of information about the same thing – a voltage, V.
- Single character names are reserved for the most basic and often used common DataObjects – such as "i" for integer value, "u" for units, etc.
- Do not use "$" or "_" or other "delimiters" in standardized names because they may not translate easily in some application layers or are reserved to assist in translation to specific application layers.
- Names with three or fewer characters are reserved for standardization by standards bodies.

5.7 Mapping the CASM to BACnet, LONTalk, and CEBus

This section provides a model for constructing translations between the common model of services presented in this report and BACnet, LONTalk, and CEBus. The LAN protocols to be mapped to are principally non-hierarchical in nature. All three are similar in that their object models allow for single level nesting of object attributes. For example, in BACnet, an object can have properties. However, properties cannot have sub-properties that are addressable through the protocol in BACnet.

For CEBus and LONTalk, the mappings from CASM show a table-based translation on a per element basis. This can be viewed as "manually" flattening the hierarchy.

For BACnet, this report proposes extensions to the standard that can represent hierarchical information.

5.7.1 Proposed Extensions to BACnet

CASM is similar to BACnet in many respects. One principal difference is the use of highly structured hierarchical structures to represent the relationship between information in a communicating device. A second principal difference is the method of referencing BACnet properties in messaging.

In CASM, an instance of a DataObject is addressed by name. This permits a message such as the following to write real-time pricing data to be understood by all devices that receive the message without any specific tailoring of the message to individual devices:

SetDataObjectValues(“All”, “Tariff.SP.Cmps[1].Pricing.Prices”, <data>)

where:

SetDataObjectValues:	Service to write one or more DataObjects.
“All”:	Implies a broadcast to all LogicalDevices.
“Tariff.SP.Cmps[1].Pricing.Prices”:	The name of the DataObject to be written – the Prices component, a setpoint SP Functional Component of the first element Cmps[] array of the TARRIF DeviceModel.
<data>:	The data to be written.

Representing the “Prices” in BACnet would have to be as a Property in BACnet object. However, because BACnet object properties are addressed through a BACnetObjectIdentifier and a BACnetPropertyIdentifier, identity of Prices will be different in all BACnet devices.

Therefore, mapping CASM to BACnet must occur on two levels. The first is the mapping of the "leaves" of the hierarchical model observed over the WAN. This primarily involves the translation of CASM DataObjects to BACnet Properties. In this case, a table-based mapping can be used. The second level is to map the hierarchy itself and to allow for the same kind of “name-based” addressing of information to interoperably access the same information on different BACnet devices where their BACnetObjectIdentifiers are different. To enable this “name-based” addressing within BACnet requires the definition of a new BACnet object type and new services that use the CASM style name-based addressing of information. To this end, the StructuredView object type is proposed:

StructuredView	An object that aggregates existing BACnet properties into common functions. This object supports the CASM DataObject hierarchy.

On a simple basis, the StructuredView object is a list of reference structures that describes how to assemble other BACnet object types existing in the device into an organized set. A key advantage of representing devices this way is that only a single class need be defined to extend BACnet to represent all devices, as opposed to representing each device as a new structured BACnet class.

Along with the new object type, a proposed extension to the syntax of BACnet would permit name-based addressing within StructuredView object type.

5.7.1.1 StructuredView Object Type

This StructuredView object type is proposed to enable BACnet to interoperably represent groupings of BACnet objects that collaborate to represent behavior that CASM calls DataObjects. A StructuredView object exists for each LogicalDevice to be represented. The properties of the StructuredView are shown in the table below.

Table 5-2:Properties of the StructuredView Object Type

Property Identifier	Property Datatype	Conformance Code
Object_Identifier	BACnetObjectIdentifier	R
Object_Name	CharacterString	R
Object_Type	BACnetObjectType	R
Description	CharacterString	O
List_Of_PropertyNames	BACnetARRAY[N] of CharacterString	R
List_Of_Component_Ids	BACnetARRAY[N] of BACnetObjectPropertyReference	R

where:

Object_Identifier
This property, of type BACnetObjectIdentifier, is a numeric code that is used to identify the object. It shall be unique within the BACnet device that maintains it.

Object_Name
This property, of type CharacterString, shall represent a name for the object that is unique within the BACnet Device that maintains it. The minimum length of the string shall be one character. The set of characters used in the Object_Name shall be restricted to printable characters.

Object_Type
This property, of type BACnetObjectType, indicates membership in a particular object type class. The value of this property shall be StructuredView.

Description
This property, of type CharacterString, is a string of printable characters whose content is not restricted.

List_Of_PropertyNames
This property is a list of one or more structured CASM names representing DataObjects. They appear as if there were a named property in this StructuredView object for each name.

List_Of_ComponentIDs
This property is a list that contains the values of corresponding BACnet objects and properties that contain the primitive values of the elements in List_Of_ComponentNames.

5.7.1.2 New ReadProperty Syntax to Allow Read Property by Name

To effect name-based binding of properties within a BACnet device to WAN messages, a modification to the syntax of Object Access Services is proposed. Note the new tag [3] in the following ASN1 description:

```
ReadProperty-Request          ::= SEQUENCE {
    objectIdentifier          [0]   BACnetObjectIdentifier,
    propertyIdentifier        [1]   BACnetPropertyIdentifier,
    propertyArrayIndex        [2]   Unsigned                   OPTIONAL
                                    -- used only with array datatype
                                    -- if omitted with an array the entire array
                                    is referenced
    propertyName              [3]   CharacterString   (SIZE(1..32))   OPTIONAL
                                    -– To access property by name
    }
```

The inclusion of propertyName allows a CASM DataObject name to be used to access a property in a StructuredView object. The implementation of Object Access Services on StructuredView objects requires the BACnet server to use the property reference to “look up” the property indirectly referenced through the corresponding PropertyID.

5.7.2 Mapping CASM Objects and Services to BACnet

With the addition of the StructuredView object and the ReadProperty syntax extension proposed, it is now possible to present the following mapping of CASM to BACnet:

Table 5-3: Mapping of CASM Objects to BACnet

CASM Object Class	BACnet Object Type
DataType	Property Data Type
DataObject	Named Property of StructuredView
FunctionalComponent	Named Property of StructuredView
DeviceModel	Named Property of StructuredView
LogicalDevice	StructuredView Object
DataSet	Group Object
Server	BACnet Device

Table 5-4 Mapping of CASM DataObject Services to BACnet

CASM DataObject Service	BACnet Service
Get DataObject Values	Read Property Multiple By Named Property
Set DataObject Values	Write Property Multiple By Named Property
Set DataObject Values (unconfirmed)	UnconfirmedCOVNotification-Request By Named Property
Get DataObject Attributes	Read Property (BACnetPropertyReference = object-type) By Named Property

5.7.3 Mapping to CEBus

A complete mapping of CASM to CEBus would require a substantial modification to the CEBus standard itself and is outside the scope of this project. However, the mapping tables presented below illustrate the strategy a Gateway device might use to affect a translation. By constructing custom contexts to represent the functions of LogicalDevices and DataSets, a given DataObject can be translated and conveyed via CEBus.

For certain of the components of the models presented in this report, there exists a correspondence to a CEBus Context as defined by the CEBus Industry Council. In these cases, the mapping table in a gateway would recognize this correspondence.

Table 5-5: Mapping of CASM Objects to CEBus

CASM Object Class	CEBus Object Class
DataType	Instance variable
DataObject	Object
FunctionalComponent	Object
DeviceModel	Object
LogicalDevice	Context
DataSet	Context
Server	CEBus device

Table 5-6: Mapping of CASM DataObject Services to CEBus

CASM DataObject service	CEBus Service
Get DataObject Values	GetValue
Set DataObject Values	SetValue
Set DataObject Values (unconfirmed)	SetValue, unacknowledged service
Get DataObject Attributes	Context control object of LogicalDevice

5.7.4 Mapping to LONTalk

A complete mapping of CASM to LONTalk would require a substantial modification to the LONTalk standard itself and is outside the scope of this project. However, the mapping tables presented illustrate the strategy a Gateway device might use to affect a translation.

Table 5-7: Mapping of CASM Objects to LONTalk

CASM Object Class	LONTalk Object Class
DataType	SNVT type
DataObject	SNVT
FunctionalComponent	SNVT
DeviceModel	SNVT
LogicalDevice	SNVT
DataSet	t.b.d.
Server	LON

Table 5-8: Mapping of CASM DataObject services to LONTalk

CASM DataObject service	LONtalk Service
Get DataObject Values	t.b.d.
Set DataObject Values	t.b.d.
Set DataObject Values (unconfirmed)	t.b.d.
Get DataObject Attributes	t.b.d.

6 Definition of Data Models

This section describes the proposed set of abstract models that can be used in providing the services presented in earlier sections.

6.1 Modeling Philosophy

What follows is an extremely detailed description of what can be considered a vocabulary of device modeling for the subjects presented. What this means is that although a prodigious degree of detail is presented, not all of it is intended to be implemented in any given instance.

An important strength of the modeling techniques presented in this report is inherent support of optional components and liberal customization. This means that the composition of information models in which arbitrary subsets of the definitions are included in an implementation can always be determined. The components included in a given instance can always be matched up with their definitions. Thus, the detailed models can be thought of as a dictionary of *how to say* rather than *what must be said*.

Much of the definitional detail in this section was derived from substantial modeling efforts by groups such as UCA, ANSI C12, IEEE SCC31, BACnet, LONTalk, International Alliance for Interoperability (IAI), and NOAA. This section endeavors to extract the knowledge from their years of work in a common format and object model.

In the conversions and derivations from the original material to the presentation in this section, liberal license has been taken to reform the work. An attempt was made to optimize the representation of the information for the CASM object model as well as a common presentation format for this report. There will *not* be a one-to-one correspondence between the components of the models of this work and the resource material upon which they are based.

On first review, a reader might consider the level of detail in the models excessive. However, many of these models were based on those of comparable detail developed by workers and manufacturers in the industry segments addressed. Therefore, the level of detail is in fact essential to the proper description of information to support the potential services of the future. The revenue metering models contain precisely this level of detail. It can be considered a good example for potential definitions of products of interest in the HVAC industry.

Given that CASM provides a rich modeling environment, a given model can be designed so that it is Spartan or Baroque. In general, models are kept to three or four levels of nested structural information. This constraint, while not absolute, facilitates mapping into some protocols. Consistency to the extent that it can be maintained contributes to ease of understanding.

At the time of this writing, most small electronic devices do not include floating point manipulation. In addition, virtually all measurements are made with analog to digital converters that produce integer values with a resolution of 8 to 16 bits. For this reason, measurements in CASM are often represented primarily with an integer to represent these bits of precision, and, a floating point scale (a constant), and an optional floating point offset, to complete the description of the measurement. However, analog values that have a large dynamic range, and that are often used in primarily large computer platforms, are often represented directly as floating point numbers. The relationship between a floating point value and the integer value is as follows (f = floating point value, i = integer value, s = scale, o = offset):

$$f = i * s + o \tag{1}$$

It is also a goal of the models developed for this report to be generic rather than specific. Examples of equipment or services upon which the models are based were abstracted and generalized to arrive at the models presented.

6.2 Conventions Used in this Section

6.2.1 Model Component Tables

In CASM, all models are constructed of DataObjects. DataObjects, as described in the mapping section (see Section 5.5) are simple or structured objects that are themselves composed of other DataObjects. In this section, the component DataObjects of the models are referred to simply, as components.

The following table format illustrates how the data models are presented in this section:

Component Name	CLASS	FC	Description
Prof	STRUCT		Profile
|__t	t	MX	Timestamp of last record

Name of this component

Describes the inherited data type of this component

Functional Component grouping of this element

Brief description of component

Note that most presented models sort their components by FC class. Remember that FC, Functional Components, are groupings of common components of data models based on their generic purpose (such as DC for documentation, CF for configuration information, …). Also, mandatory components within each FC class are listed first, followed by the optional components (note: that mandatory/optional status of a component is not determined in this report). This is done to facilitate potential optimization during transport when the models are mapped to communications protocols. For this reason an order other than alphabetical may be found. The most commonly used components are found first, followed by increasingly rarely used components.

If a structured component has an identified FC grouping, then all subcomponents of this structure are assumed to have that same grouping. If the elements of the structure belong to differing groupings, then the structure is tagged with no grouping and each element is appropriately identified.

6.2.2 Example Component Tables

The following figure shows how examples are presented for the representation of components of the data models in this report:

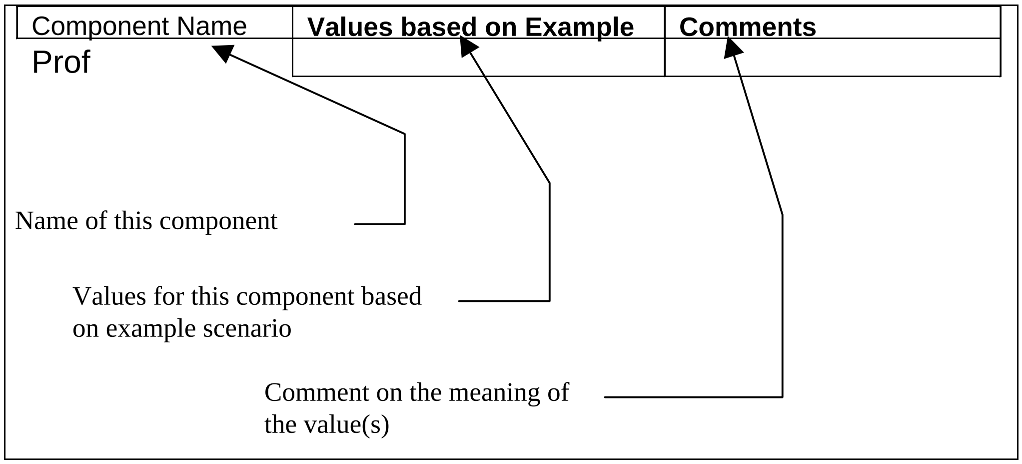

Figure 6-1: Representation of Components in CASM

In these examples, actual values of sample components are provided. The following conventions are used:

Floating point number:	0.0E-4
Decimal integer:	0123456
Hexadecimal integer:	0x1234
Binary constant (as many bits as necessary to define value of bit field shown is 2 bit example):	b'11'
Structured set:	{ value component1, value component2, … }
Array component:	ArrayName [0]
Elements of array	{ value 1, value2, value3, value4, …}
Array of structures (shown is array of two structures of two elements each)	{ {1,2}, {3,4} }
Time and date	0111199@3:00:00.00
Binary time and date	{miliseconds since midnight, days since 1/1/1984}

6.3 Common Models

This section describes some common models that are reused throughout the section. It begins with a set of common abbreviations that are used to construct DataObject names. The clear purpose of the abbreviations is to promote a consistency of naming to enhance the communicative ability of the names developed.

Following the common abbreviations are a summary of primitive (non-structured) DataObjects that are commonly contained in the data models to be presented. Rather than provide only an extraction of those that are used, this section extracts the complete set from the GOMSFE work [EPRI, GOMSFE 1999].

Because much of this data is extracted from the references that describe them in greater detail, they are only presented here in raw form without the other descriptive information. The reader is referred to the CASM and GOMSFE references for more information [CASM 1999], [GOMSFE 1999].

Next are some common structured components that are used in modeling the services of this report. They include a model of a measurement, AI, a profile or time series of a measurement, Prof, and models of a universal scheduling component, Schd & TimEvt, and holiday schedule component, RDate.

6.3.1 Common Abbreviations

The following table is extracted from the GOMSFE reference [EPRI, 1999] and [GOMSFE, 1999]. It contains a set of abbreviated terms that can be used to construct consistently named components. The goal of this consistency is to allow for the familiarity of the naming conventions to aid ultimately in the understanding of the models. The abbreviations are terse because they will be transported over communications networks as part of the transport protocols that implement the services for interacting with the models.

Table 6-1: Common abbreviations for use in model component naming

Abbr	Term
A	Ampere
Abbr	Abbreviation
Acc	Accumulator
Acs	Access
Act	Active
Actn	Action
Adr	Address
Alm	Alarm
Alw	Allowed
Amb	Ambient
An	Analog
Ang	Angle
App	Applications
Arc	Arcing
Ar	Arrestor
Arr	Array
Auto	Automation
Avg	Average
Batt	Battery
Bctr	Bandcenter
Bef	Before
Blind	Blinder
Blk	Block, Blocking
Bot	Bottom
Buf	Buffer
Bwid	Bandwidth
Cal	Calculated
Cap	Capacitance
Cap	Capacitor Bank
CapC	Capacitor Bank Controller
Char	Characteristic
Chg	Change
Circ	Circulating
Ckt	Circuit
CB	Circuit Breaker
Class	Class
Cld	Cold

Abbr	Term
Cls	Close
Cmd	Command
Cnd	Condition
Cns	Constraint
Cnt	Count
Coef	Coefficient
Comb	Combustible
Comm	Communications
Comp	Compensate
Con	Connected
Cond	Conductor
Conf	Confidence
Consv	Conservator
Cont	Continuous
Crv	Curve
CT	Cur Transformer
Ctl	Control
Cur	Current
Dat	Data
DC	Direct Current
Del	Delay
Den	Density
Desc	Descriptive
Dev	Device
DF	DevFct
Diel	Dielectric Strength
Diff	Difference /Differential
Dir	Directional
Dis	Disable
Disc	Discrepancy
Diss	Dissipation
Dist	Distance
Dmd	Demand
Dn	Downed
DOW	Day Of Week
DrO	Drop Out
DS	DevSt

Abbr	Term
Dsch	Discharge
Dst	Destination
Dur	Duration
Ena	Enable
Enr	Enroll
Ent	Entry
Ex	Exchanger
Evt	Event
Fact	Factor
Fail	Failure
Fct	Function
Fld	Field
Flg	Flag
Flt	Fault
Flw	Flow
Fmt	Format
FPF	Fwd Pwr Flow
Frz	Freeze
Fund	Fundamental
Fwd	Forward
Gas	Gas
Grp	Group
Ha	Harmonics
Hdw	Hardware
Hi	High
Hrs	Hours
Hum	Humidity
Hyst	Hysteresis
Hz	Frequency
Id	Identity
Img	Image
In	Input
Incr	Increment
Ini	Initiate
Ins	Inside
Int	Interval
Intg	Integrity
Intlk	Interlock

Abbr	Term
Intp	Intertap
Inv	Inverse
IOC	Instantaneous Over Current
Kno	Knowledge
Lat	Latch
L	Lower
LodCtr	Load Center
Ld	Lead
LDC	Line Drop Compensation
Leak	Leakage
Len	Length
Lev	Level
Lg	Lag
Lin	Line
Lmt	Limit
Lo	Low
Loc	Location
Lod	Load
Lst	List Of
M	Main
Mag	Magnitude
Maj	Major
Max	Maximum
Mdl	Model
Med	Medium(physical)
Min	Minimum
Mnr	Minor
Mot	Motor
MR	MxRef
MT	MxTyp
Mtr	Meter
Mult	Multiplier
Mx	Measurement
Na	Name
Neg	Negative
Neut	Neutral
New	Newest
Num	Number
Nxt	Next
OC	Over Current
OD	OperDev
Off	Off
Ofs	Offset
Old	Oldest
On	On
Oper	Operate
Opt	Option
Optl	Optional
Ots	Outside

Abbr	Term
Out	Output
OV	Over Voltage
Ovr	Overflow
Own	Owner
Pa	Partial
PA	Preventative Autotransformer Winding
Par	Parameters
Pct	Percent
Pd	Period
PF	Power Factor
Pfd	PwrFlw Direction
Phs	Phase
Pk	Peak
Pls	Pulse
Po	Polar Coordinates
Pos	Position
Posi	Positive
PP	Phase to Phase
Pres	Pressure
Pri	Primary
Pro	Protocol
Prs	Present
Pt	Point
Pu	Pickup
Pw	Password
Pwr	Power
Qu	Quality
Quad	Quadrilateral
Quan	Quantity
R	Raise
Rat	Ratio
Rch	Reach
React	Reactive
Rec	Reclosing
Recl	Recloser
Rect	Rectangular Coordinates
Red	Reduction
Ref	Reference
Reg	Regulation (%)
Rem	Remote
Res	Resistance
Rest	Resistive
Req	Required
Rev	Revisions
Rnbk	Runback
RPF	Rvs Pwr Flow
Rpt	Report
Rs	Reset
Rsd	Residual

Abbr	Term
Rtg	Rating
Run	Running
Rvs	Reverse
Rx	Receive
SBO	Select Before Operate
Sched	Schedule
Se	Series
Sec	Secondary
Sel	Select
Seq	Sequence
Ser	Serial
Set	Set
Sft	Software
Sg	Surge
Sh	Short
Slp	Slope
Smp	Samples
Src	Source
St	Status
Start	Start
Stop	Stop
Sub	Substation
Sup	Supply
Sus	Sustained
Sw	Switch
Sync	Synchronizer
Sys	System
Tag	Tag
TDD	Total Demand Distortion
Temp	Temperature
Ter	Tertiary
THD	TotalHarmonic Distortion
Thre	Threshold
Tim	Time
Tmr	Timer
Tot	Total
Trfr	Transfer
Trg	Triggers
Torq	Torque
Trp	Trip
Tst	Test
Tx	Transmit
Txf	Transformer
Typ	Type
U	Upper
Uneq	Unequal
Unit	Unit
Unk	Unknown
UPF	Unk Pwr Flw

Abbr	Term
Use	Usage
UV	Under Voltage
V	Volts, Voltage
VA	VoltAmps
Vac	Vacuum
VAr	VAr
Vec	Vector
Vnd	Vendor
VR	V Regulator
VRed	V Reduction
VT	Voltage Transformer
W	Watt
Wav	Waveform
Wrn	Warn
Wrp	Wrap
Z	Impedance

6.3.2 Standard CASM Primitive Components

The following table lists common CASM components used to build interoperable models in this document. This list is has been defined in UCA documents [EPRI, CIWG, 1997].

Table 6-2: Common Primitive Components

Common Components		
Name	**Description**	**Data Type**
b	binary value	BOOL
b2	Binary 2 bit Value	BSTR2
d	Description	VSTR32
db	Deadband	INT16U
f	FloatingPointValue	FLT32
ff	Frozen FloatingPoint Value	FLT32
hl	HighLimit	INT16S
hhl	HighHighLimit	INT16S
ll	LowLimit	INT16S
lll	LowLowLimit	INT16S
i	IntegerValue	INT16S
fi	Frozen Integer Value	INT16S
o	offset	FLT32
q	quality	BSTR16
r	Running Total	INT32S
fr	Frozen Running Total	INT32S
s	scale	FLT32
t	Timestamp	BTIME6
tu	Hires Tim estamp	OSTR8
ft	Frozen Timestamp	BTIME6
pp	PsuedoPoint	BOOL
u	Unit	ENUM16
AccRs	AccumulatorReset	BOOL
AccSet	AccumulatorSet	BSTR16
ActTagArr	ActiveTagArray	BSTR8
Ancestry	CASM class ancestry	VSTR32
AnFmt	AnalogFormat	VSTR6
BLOB	Binary Large Object	BLOB
BnkCon	Bank Connection	ENUM8
BufTim	BufferTime	INT32U
CID	Canonical addressing ID	INT32S
CktID	CircuitID	VSTR32
CktPhs	CircuitPhases	ENUM8
Class	Device Class	VSTR32
CommAdr	CommunicationAddress	VSTR16
CommRev	CommunicationsRev	VSTR8
ContCurRtg	ContinuousCurrentRtg	VSTR16
Count	Count of records	INT16U
CurEnt	Current Entries	INT32U
CriRpt	Critical report	BOOL
DatSetNa	Data Set Name	VSTR16
DestAE	Destination AE Title	VSTR32
DevFct	DeviceFunction	INT16U

Common Components		
Name	**Description**	**Data Type**
DevMdls	DeviceModels	VSTR128
DevSt (DS)	DeviceState	b2
DOW	Day Of Week	ENUM8
DOWSched	Day Of Week Schedule	BTIME4[6]
DschTimDel	Discharge Time Delay	INT16U
Enable	Enable some function	BOOL
EncOpt	Encoding options	BSTR8
Enroll	ECB name to enroll	IDENT
EOrBDesc	Enumeration or bitstring descriptive strings	VSTR64[]
EvaCns	Evaluation constraints	IDENT
EvaCri	Evaluation criteria	IDENT
EvaFct	Evaluation function	VSTR32
EvaPar	Evaluation parameters	IDENT
EvtEna	EventEnable	BOOL
FltCurDur	FaultCurrentDuration	INT16U
FltCurRtg	FaultCurrentRtg	VSTR16
Fmt	Format	ENUM8
FrzEna	FreezeEnable	BOOL
FrzPd	FreezePeriod	INT32
FwdPwrHa	ForwardPowerHa	FLT32[31]
HwRev	HardwareRev	VSTR8
HzRtg	Frequency Rating	VSTR32
InDat	Input data name	IDENT
IntgPd	IntegrityPeriod	INT32
LinLenm	Line Length in Meters	INT16U
Loc	DeviceLocation	VSTR128
LogEna	LogEnable	BOOL
LogEnr	ECB to enroll	IDENT
LogNam	Log Name	VSTR32
LogSize	Log table size	INT16U
LogWrp	Log wrapped	BOOL
MAC	MediumAccessControl	INT8U
Mdl	Model	VSTR32
Med	PhysicalMedium	ENUM8
MxRef	MeasurementReference	ENUM8
MxTyp	MeasurementType	ENUM8
MxLoc	MeasurementLocation	VSTR32
Name	OwnerDeviceName	VSTR32
NewTim	newest time	BTIME6
NumBits	NumberBits	INT16U
NumPls	NumberPulses	INT16U
NumSmp	NumberSamples	INT16U
NumUnit	Number of Units	VSTR32

Common Components		
Name	Description	Data Type
OffDur	OffDuration	INT32U
OldEnt	Oldest Entry	INT32U
OldTim	Oldest time	BTIME6
OnDur	OnDuration	INT32U
OperDev (OD)	OperateDevice	b2
OperLogic	Operating Logic	ENUM8
OptFlds	Optional fields to include	BSTR8
OutDat	Output DataSet name	IDENT
OvrST	Overflow status	BOOL
Own	Owner	VSTR32
Po	Polar Coordinates	[Mag, Ang]
Pro	Protocol	ENUM8
PwrHa	Power Harmonics	FLT32[31]
QuRptEna	QualityReportEnable	BOOL
RBEPd	Report Period	INT32U
Rect	Rectangular Coordinates	[x, y]
RptEna	ReportEnable	BOOL
RptID	Report ID	VSTR32
RvsPwrHa	ReversePowerHa	FLT32[31]
SBO	SelectBeforeOperate	IDENT
SBOEna	SBOEnable	BOOL
SelTimOut	SBO Select Time Out	INT8U
SeqNum	Sequence number	INT8U
SerNum	SerialNumber	VSTR32
SftRev	SoftwareRev	VSTR8

Common Components		
Name	Description	Data Type
SmpRate	SampleRate	INT16U
StartTim	Start Time	BTIME6
State	State	BOOL
TagD	TagDescription	VSTR128
TagID	TagID	INT8U
TagOwn	TagOwner	VSTR32
TagTyp	TagTypePermitted	BSTR8
TempRtg	TemperatureRating	VSTR16
TimOfFrz	TimeOfFreeze	BTIME6
TimRptEna	TimeStampReportEna	BOOL
TrgOps	Trigger Options	BSTR8
Trgs	NumOfTriggersBefore Report	INT16U
UnitVArRtg	UnitVArRtg	VSTR32
UnkPwrHa	PowerHarmonics (direction unknown)	FLT32[31]
UseST	Utilization status	BOOL
VArRtg	VarRating	VSTR16
VARtg	VARating	VSTR16
Vnd	Vendor	VSTR32
VRtg	VoltageRating	VSTR16
WrnLev	Log warning level	INT16U
WrnST	Warn status	BOOL

6.3.3 Measurement Model

Many of the models presented in this section contain various measurements such as temperature, humidity, and mass flows. For those familiar with the BACnet analog object type, many of the sub-components of the AI model are similar to the properties of that object.

The measurement model presented was developed as part of the UCA 2 effort [UCA 2.0, 1997].

Component Name	CLASS	FC	Description
AI	STRUCT		Measurement
|__i	i	MX	Integer value
|__f	f	MX	Floating point value
|__t	t	MX	Timestamp
|__q	q	MX	Quality
|__ff	ff	MX	Frozen floating point value
|__fi	fi	MX	Frozen integer
|__ft	ft	MX	Frozen timestamp
|__u	u	CF	Units of measure
|__s	s	CF	Scale
|__o	o	CF	Offset

Component Name	CLASS	FC	Description
|__min	min	CF	Min value
|__max	max	CF	Max value
|__incr	incr	CF	Increment
|__MxTyp	MxTyp	CF	Measurement type
|__MxRef	MxRef	CF	Measurement reference
|__MxLoc	MxLoc	CF	Measurement location
|__SmpRat	SmpRat	CF	Sampling rate
|__NumSmp	NumSmp	CF	Number of samples combined
|__pp	pp	CF	Pseudo point
|__db	db	SP	Deadband for change
|__hl	hl	SP	Hi limit
|__ll	ll	SP	Low limit
|__hhl	hhl	SP	High high limit
|__lll	lll	SP	Low low limit
|__d	d	DC	Description of measurement

i
Integer Value, the actual value of the analog point.

f
Floating Point Value, for *Analog Values*, the floating point representation of the *Analog Value* calculated by:

*Floating Point Value = Integer Value * Scale + Offset*

t
Timestamp.

q
Quality, used to indicate if an object value is valid, and if not, the reason for being invalid. Each *Quality* indication is represented as a bit within the Quality component. The bits representing Quality are:

- **Invalid** - Indicates whether or not the associated value is valid or not. If clear (0), the value of this point is valid and can be used in calculations, alarms, etc. If set to (1), the reported value of this point may not be correct and therefore should not be used.
- **Comm Fail -** Indicates communication status. If set (1), this bit indicates that one of the reasons the *Validity* bit is set is that the object has lost communications with the device actually gathering the value of the point.
- **Forced -** Indicates how the value was established. If set (1), this bit indicates that the reported value of this pointis not necessarily the actual value. The point has been “forced” to report this value either locally, or via a write operation from the master. The *Validity* bit may be set or clear when *Forced* is set, since the forced value may or may not be valid.
- **Over Range -** This is only applicable to *Analog Values*. If set (1), this bit indicates that the value is invalid because the value being measured has exceeded the physical capabilities of the hardware performing the measurement. This bit thus indicates that one of the reasons the *Validity* bit is set is that the value is over range.
- **Bad Reference -** This is only applicable to *Analog Values*. If set (1), this bit indicates that the value is invalid because the reference value used to calibrate the *Analog Value* is incorrect.

Bit Number	Quality
0	Reserved
1	Invalid
2	Comm
3	Forced
4	Over Range
5	Bad Reference
6-15	Unassigned (future)

ff
Frozen floating point value.

fi
Frozen value of the "i" component.

ft
Frozen timestamp.

u
Units of measure. All units of measure are represented as primitive SI units. The values of u are enumerated in the following table. The integer representations of *SIUnits* and derived *SIUnits* are:

Integer Value	Quantity	Unit Name	Symbol	UCA 2.0
	Base Units			
1	none	dimensionless	none	none
2	length	meter	m	m
3	mass	kilogram	kg	kg
4	time	second	s	s
5	current	ampere	A	A
6	temperature	Kelvin	K	T
7	amount of substance	mole	mol	
8	luminous intensity	candela	cd	cd
9	plane angle[11]	radian	rad	r
10	solid angle	steradian	sr	
	Derived Units			
21	absorbed dose	Gray (J/Kg)	Gy	
22	activity	becquerel (l/s)	q	
23	relative temperature	degrees Celsius	°C	
24	dose equivalent	seivert (J/kg)	Sv	
25	electric capacitance	farad (C/V)	F	
26	electric charge	coulomb (AS)	C	
27	electric conductance	siemens (A/V)	S	
28	electric inductance	henry (Wb/A)	H	H
29	electric potential	volt (W/A)	V	V
30	electric resistance	ohm (V/A)	Ω	Ω
31	energy	joule (N m)	J	
32	force	newton (kg m / s^2)	N	
33	frequency	hertz (1/s)	Hz	Hz
34	illuminance	lux (lm / m^2)	lx	lx
35	luminous flux	lumen (cd sr)	Lm	Lm
36	magnetic flux	weber (V s)	Wb	

[11] The UCA document [CASM, 1998] is not consistent with the orthogonal SI units as documented in [Taylor, B., 1995]. The UCA document presents a second *plane angle* specified in degree, which is omitted in this report t

Integer Value	Quantity	Unit Name	Symbol	UCA 2.0
37	magnetic flux density	tesla (Wb / m^2)	T	
38	power	watt (J /s)	W	W
39	pressure	pascal (N / m^2)	Pa	
	Extended Units			
41	area	square meter (m^2)	m^2	
42	volume	cubic meter (m^3)	m^3	
43	velocity	meters per second (m / s)	ms^{-1}	
44	acceleration	meters per second^2 (m / s^2)	ms^{-2}	
45	volumetric flow rate	cubic meters per second (m^3 / s)	m^3s^{-1}	
46	fuel efficiency	meters / cubic meter (m / m^3)	ms^3	
47	moment of mass	kilogram meter (kg m)	M	
48	density	kilogram / cubic meter (kg / m^3)		
49	viscosity	meter square / second (m^2 / s)		
50	thermal conductivity	watt / meter Kelvin (W / m K)		
51	heat capacity	joule / Kelvin (J / K)		
52	concentration	parts per million	ppm	ppm
	Industry Specific Units	**Electric Units**		
61	apparent power	volt ampere (VA)	VA	VA
62	real power	watts (I^2R)	W	W
63	reactive power	volt ampere reactive (VISinθ)	VAr	VAr
64	phase angle	degrees	θ	θ
65	power factor	(dimensionless)	Cosθ	Cosθ
66	volt seconds	volt seconds (W s / A)	Vs	Vs
67	volts squared	volt square (W^2 / A^2)	V^2	V^2
68	amp seconds	amp second (A s)	As	As
69	amps squared	amp square (A^2)	A^2	A^2
70	amps squared time	amp square second (A^2s)	A^2t	A^2t
71	apparent energy	volt ampere hours	VAh	VAh
72	real energy	watt hours	Wh	Wh
73	reactive energy	volt ampere reactive hours	VArh	VArh
74	magnetic flux	volts per hertz	V/Hz	V/Hz

s
Scale to be applied to integer value, i.

o
Offset to be applied to integer value , i, multiplied by scale, s, to arrive at scaled value.

min
Minimum value.

max
Maximum value.

incr
Increment by value can change.

MxTyp
Measurement type identifies what the *Field Device Measurement* represents, i.e. the present value, peak, zero sequence component, etc. over the number of samples. The bits representing *Measurement Type* are:

Integer Value	Measurement Type
1	Present Value
2	Maximum Value
3	Minimum Value
4	Peak
5	Zero Sequence
6	Positive Sequence
7	Negative Sequence

MxRef
Measurement reference describes the phase measurement, if any, associated with the *SIUnits*, i.e., phase 1, phase 1 to phase 2, 3 phase, etc., and the location of the measurement, i.e., source side, load side, etc. The integer representations of *Measurement Reference* are:

Integer Value	*Measurement Reference*
1	Unknown
2	Phase 1
3	Phase 2
4	Phase 3
5	Neutral
6	Phase 1 To Phase 2
7	Phase 2 To Phase 3
8	Phase 3 To Phase 1
9	Phase 1 To Neutral
10	Phase 2 To Neutral
11	Phase 3 To Neutral
12	Neutral To Ground
13	3 Phase
14 -15	Unassigned (future use)

MxLoc
Location reference of measurement.

SmpRat
Sample rate.

NumSmp
Number Samples, If applicable, this is the number of samples used in the actual measurement associated with the *Measurement Type*.

pp
PsuedoPoint, flag that when set, indicates the value is substituted. For example, a measurement that is not currently being updated from an AtoD converter and has its value “stuffed.”

db
Deadband for evalutation of relative deviation.

hl
High limit.

ll
Low limit

hhl
High high limit.

lll
Low low limit.

d
Description of the component.

6.3.3.1 Example of Measurement Model

The example of a temperature measurement is presented.

Component Name	**Values based on Example**	**Comments**
AI		
|__i	1024	Corresponding to 25 degrees C.
|__t	{0x0295ed34, 0x15d5}	3/22/1999, 12:03:00.02 PM
|__q	0	Value is valid
|__u	23	Relative temperature degrees Celsius
|__s	0.024414	100 degrees FS / 4096 counts
|__o	0.0	No offset (trimmed out in hardware)
|__min	0	Minimum value reported
|__max	4095	Maximum value reported
|__incr	1	Changes in 1 count increments
|__MxTyp	1	Present value
|__SmpRat	1	Once per second
|__NumSmp	4	4 samples averaged per measurement
|__db	41	~1 degree in counts for change detect
|__d	Supply temperature of chiller	Describes measurement

6.3.4 Measurement Profile Model

This model is used to represent a time series of related measurements. In a generic way, it can represent any sequence of measurement sets that are related by a constant interval in time. The measurement profile can optionally include descriptive information about the elements of the profile, termed channels, including a complete structure containing an instantaneous value of the measurement. This structure collapses to a simple timestamp and sequence of measurement values.

Component Name	CLASS	**FC**	**Description**
Prof	STRUCT		Profile
|__t	t	MX	Timestamp of last record
|__NumChan	INT16U	CF	Number of channels
|__NumIntv	INT32U	MX	Number of intervals
|__Intvl	BTIME6	CF	Time between intervals
|__Chan[ ]			Channel descriptors
| |__AI	AI		Measurement complete descrip.
| |__Nam	VSTR32	CF	Full name of measurement
|__Data[ ][ ]	STRUCT[][]		Interval data sets for channels
|__q	q	MX	Quality of element
|__I	I	MX	Integer value of measurement

<u>t</u>
Timestamp of last record. All values in the profile were taken at a time related to this timestamp by Invl.

<u>NumChan</u>
Number of channels of data for each measurement interval.

NumIntv
Number of intervals represented in profile.

Intvl
Time between measurements.

Chan [ ]
Array of descriptions of channels of the profile.

AI
Analog Input structure of a specific measurement. Contains a subset of the components of the full measurement as required for the profile.

Nam
Full DataObject Reference for the measurement. In essence this is a handle to the measurement.

Data [] []
Array of measurement values and quality tags for the individual values. There is a set of q and i for each channel in the profile.

q
Data quality bit string for the measurement.

I
Integer value of the measurement. Note any scale and offset information required for proper interpretation would be found in the AI component for each channel in the profile.

6.3.4.1 Example of Profile Model

The following example illustrates a 24-hour temperature profile for an outdoor air sensor:

<table>
<tr><th>Component Name</th><th>Values based on Example</th><th>Comments</th></tr>
<tr><td>Prof</td><td></td><td></td></tr>
<tr><td>|__t</td><td>{0x0295ed34, 0x15d5}</td><td>3/22/1999, 12:03:00.02 PM</td></tr>
<tr><td>|__NumChan</td><td>1</td><td></td></tr>
<tr><td>|__NumIntv</td><td>24</td><td></td></tr>
<tr><td>|__Intvl</td><td>{0x02255100,0}</td><td>One hour per interval (*3600000 msec/hr)</td></tr>
<tr><td>|__Chan[0]</td><td></td><td></td></tr>
<tr><td>| |__AI</td><td></td><td>Subset of information from AI structure</td></tr>
<tr><td>| | |_i</td><td>1024</td><td>Corresponding to 25 degrees C.</td></tr>
<tr><td>| | |_t</td><td>{0x0295ed34, 0x15d5}</td><td>3/22/1999, 12:03:00.02 PM</td></tr>
<tr><td>| | |_q</td><td>0</td><td>Value is valid</td></tr>
<tr><td>| | |_u</td><td>23</td><td>Relative temperature degrees Celsius</td></tr>
<tr><td>| | |_s</td><td>0.024414</td><td>100 degrees FS / 4096 counts</td></tr>
<tr><td>| | |_o</td><td>0.0</td><td>No offset (trimmed out in hardware)</td></tr>
<tr><td>| |__Nam
|</td><td>“BMS0001/OA.MX.Tmp.i”</td><td>Outside air temperature integer measurements of building management system BMS0001</td></tr>
<tr><td>|__Data[ ][ ]</td><td>{
{0,1024},
{0,1025},
{0,1026},
{0,1028},
{0,1030},</td><td>{ (Start of Data Array)
{OK, 25 degrees}
{OK, 25.02 degrees}
{OK, 25.049 degrees}
{OK, 25.098 degrees}
{OK, 25.146 degrees}</td></tr>
</table>

Component Name	Values based on Example	Comments
	{0,1040},	{OK, 25.390 degrees}
	{0,1060},	{OK, 25.879 degrees}
	{0,1080},	{OK, 26.367 degrees}
	{0,1100},	{OK, 26.855 degrees}
	{0,1200},	{OK, 29.297 degrees}
	{0,1300},	{OK, 31.738 degrees}
	{0,1400},	{OK, 34.179 degrees}
	{0,1300},	{OK, 31.738 degrees}
	{0,1200},	{OK, 29.297 degrees}
	{0,1100},	{OK, 26.855 degrees}
	{0,1080},	{OK, 26.367 degrees}
	{0,1060},	{OK, 25.879 degrees}
	{0,1040},	{OK, 25.390 degrees}
	{0,1030},	{OK, 25.146 degrees}
	{0,1028},	{OK, 25.098 degrees}
	{0,1026},	{OK, 25.049 degrees}
	{0,1025},	{OK, 25.02 degrees}
	{0,1024},	{OK, 25 degrees}
	{0,1024}	{OK, 25 degrees}
	}	}

6.3.5 Schedule Model

Scheduling is a common activity in monitoring and control. Devices and systems are expected to follow schedules of varied degree and complexity. Simple scheduling might include the need to do something at 7:00 AM every day. More complex scheduling might describe the occupancy schedule of a commercial space during normal operating days, holidays, and during exceptional events.

A driving requirement for this model is the ability to atomically transport a simple or complex schedule. Some protocols offer schedule services and calendar services, for example. While this approach can be equally expressive, a client must know the local arrangement of these associated objects to configure a set of them.

The following schedule model is derived in part from work done in the ANSI C12.19 metering standards and in part from work done under the auspices of the CEBus Industry Council [ANSI C12.19, 1996] and [Burns, et. al., 1996]. The proposed scheduling model consists of the definition of two classes – TimEvt, and, RDate.

TimEvt is a compact, bit compressed, structure for the exchange of scheduling information. A TimEvt is assumed to consist of one or more records that describe a series of time related changes of scheduled value, termed "evt." For example, an occupancy schedule might describe transitions between the un-occupied state (Evt=0), and the occupied state (Evt=1). Alternatively, a schedule might describe a set of transitions between four tiers (Evt=0,1,2,3), for the purpose of charging time-of-use rates. An application using TimEvts is assumed to have some associated state that can change based on the timely value of Evt. Thus, in interpreting the programmed schedule, the value of Evt can be seen to change accordingly.

The Rdate class describes recurring calendar dates that represent events, holidays, and vacation days. Typically, Rdates are used to describe dates on which exceptions to normal schedules occur.

The following figure logically illustrates the processing associated with a schedule object:

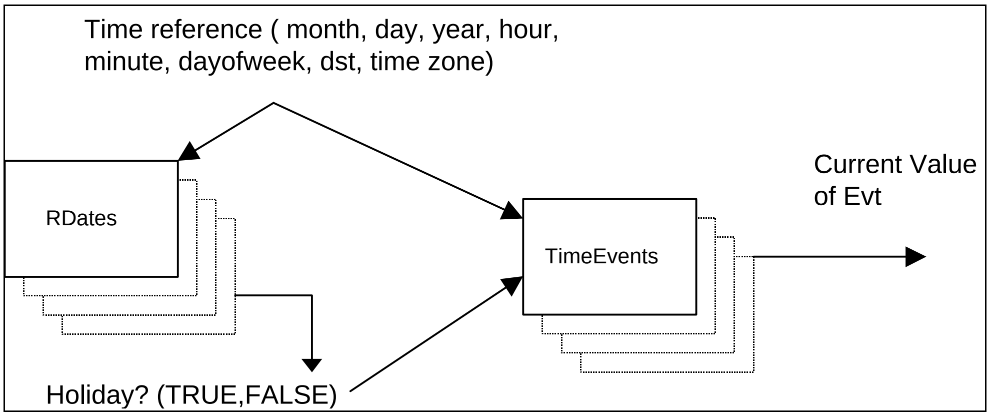

Figure 6-2 Logical View of Schedule Object

As shown in the figure, the Schedule object manages its list of TimEvts and a list of Rdates. Based on the time reference, the Rdates can be analyzed to determine the state of Holiday. This is then used along with the time reference, used as inputs to analyze the list of TimEvts. The result of this analysis is the changing value of Evt that can then be utilized for control.

6.3.5.1 Schd Model

Putting it all together, a schedule can consist of a list of TimEvts for normal and holiday schedules, and Rdates to describe which dates are normal and which are holidays or special events. In addition, there is a schedule header, SchdHdr, which describes the nature and scope of this Schd object.

Component Name	CLASS	**FC**	**Description**
Schd	STRUCT		Schedule
|__SchdHdr	STRUCT		Describes this Schd object
| |__IsEdit	BOOL	CF	Is schedule editable
| |__NumTEV	BOOL	CF	Number of TimEvts
| |__NumRDat	BOOL	CF	Number of RDates
| |__Sup	TIMEVT	CF	Kind of scheduling supported
|__TimEvts [ ]	TIMEVT [ ]	SP	Array of TimEvts
|__Rdates [ ]	RDATE [ ]	SP	Array of Rdates

SchdHdr
This structure describes the nature and features of this Schd component.

IsEdit
Is the schedule editable.

NumTEV
Number of TimEvts in the TimEvts array.

NumRDat
Number of Rdates in the Rdate array.

Sup
Type of scheduling supported. This component contains a special TimEvt where bits are set for each type of element in the TimEvt supported by this device. For example, the TimSpec component of a TimEvt contains a field for month in bits 0..3. If a Schd object wants to express no support for month, the Sup structure would contain zero for all four bits. If month were supported, all bits would be set. Refer to the details of TimEvt for descriptions of these bit fields. The summary blow identifies the meaning of the bits relative to Sup.

TimeSpec

[0]..[3]	month – 0 for no month support 0b'1111' for 12 month support
[4]..[8]	hour – 0b01100 for 12 hour support, 0b11000 for 24 hour support
[9]	holiday usage – TRUE if holidays are recognized, FALSE if ignored
[10]	holiday mode – TRUE if holiday or non-holiday scheduling support, FALSE exclude holiday
[11]..15]	day – 0b11111 if day of month support is included
[16]	once – TRUE if discard after use is supported
[17]	continue – TRUE if sequence of TimEvts supported
[18]..[23]	minute – 0b111111 if minutes are supported, 0b110000 for 15 minute only resolution

DowSpec

[0]	DowMode – TRUE if DOW modifiers supported, FALSE only simple dow supported
[1]	modifier – TRUE if nth day of week supported
[2]	modifier – TRUE if last or first day of week in month supported
[3]	modifier – TRUE if odd / even / or alternate is supported
[4]	modifier – TRUE if postpone / advance feature is supported
[5]..[7]	<reserved>

Evt range of Evt value 0..n.

TimEvts[]
An array of timing statements for the schedule

RDates[]
An array of recurring dates that describe exceptional days for alternate scheduling.

6.3.5.2 TimEvt Model

The proposed model of a time event of a Schedule is as follows:

Component Name	CLASS	FC	Description
TimEvt	STRUCT		Profile
|__TimSpec	BSTR24	SP	Date specification
|__DowSpec	BSTR8	SP	Day of week constraints
|__Evt	INT8S	SP	Event code

TimSpec
A series of bits that describe the time and date referenced.

[0]..[3]	month – referenced 1..12, 15 is any month
[4]..[8]	hour – referenced 0..23, 31 is any hour
[9]	holiday usage – defined for holiday
[10]	holiday mode – TRUE include holiday, FALSE exclude holiday
[11]..15]	day – referenced - 1..31, 0 is any day
[16]	once – discard after firing

[17]	continue – from previous TimEvt
[18]..[23]	minute – minute referenced 0..59, 63 is any minute.

month
The calendar month 1=January .. 12=December, 15=accept any month.

hour
The hour of the day 0..23,31=accept any hour.

holidayUsage
Defined for matching holiday state, 1=ignore holidays, 0=recognize holidays.

holidayMode
Define whether to accept on holidays, 1, or exclude holidays, 0.

day
The day of the month, 1..31, 0=accept any day of the month.

once
If TRUE, 1, this TimeEvent is to be used until its criterion is met. After that it is to be automatically discarded from the list. If FALSE, 0, the TimeEvent is to be continuously monitored until manually deleted.

continue
This TimeEvent is bound to the one before it in the list. This means that it can be edited or deleted only as a set with others it is bound to. A sequence of three TimeEvents can be bound together by setting the continue bit to TRUE for the second and third TimeEvent in the sequence. Software that is used to check for schedule conflicts uses this relationship to recongnize uninterruptable periods of timing from unique events that are not related.

minute
The minute of the hour, 0..59, 63=accept any minute.

DowSpec
A set of bits that describe day of week related rules. The DowSpec substructure describes constraints based on day of week. Included are subsets of days of the week, alternate day schedules, and selection of occurrances of the day of week during the month.

[0]	DowMode – is this dow (0) bitmap or alternate (1)

If the dowmode is 0, then this is a map of days of week. For example Saturdays and Sundays.

[1]	Sunday
[2]	Monday
[3]	Tuesday
[4]	Wednesday
[5]	Thursday
[6]	Friday
[7]	Saturday

If the dowmode is one, then there are two fields, the <modifier>, and, <whichdow>.

[1]..[4]	modifier – selector of dow special modifier
[5]..[7]	whichdow – the selected day of week Sun=0, Sat = 6

In this case, the mode specifies one of sixteen special cases. The <whichdow> specifies the day of week defined by the special cases (if required):

Mode value	**Description**
[1]	1st <whichdow> of month (eg. first Tuesday)
[2]	2nd <whichdow> of month
[3]	3rd <whichdow> of month
[4]	4th <whichdow> of month

[5]	last <whichdow> of month
[6]	odd days of month (1,3,5,...)
[7]	even days of month (2,4,6,...)
[8]	alternate <whichdow> days eg every other Wednesday
[9]	postpone til Monday if Sunday
[10]	Advance to Friday if Sunday
[11]	Postpone to Monday if Saturday
[12]	Advance to Friday if Saturday
[13]	Postpone to Monday if Sunday or Saturday
[14]	Postpone to Monday if Sunday, advance to Friday if Saturday

whichdow value	**Description**
[0]	Sunday
[1]	Monday
[2]	Tuesday
[3]	Wednesday
[4]	Thursday
[5]	Friday
[6]	Saturday

Evt

A code that represents the changed state of what is being scheduled. The Evt is the number that is to be asserted as the state of the TimeEvent, if a combination of the criterion is met.

6.3.5.3 RDate Model

This section borrows from ANSI C12.19 the structure of repeating date specifications -- Rdate. The Rdate, or recurring date, structure allows a holiday date to be specified in two bytes of information. This information is strategically packed. Yet, it can express both simple dates -- for example 12/31 -- as well as complex dates such as the first Monday after the 21st of February, etc... This recurrence can be yearly, monthly, weekly or based on a constant cycle of up to 64 days.

Component Name	CLASS	FC	Description
Rdate	BSTR16		Recurring date

Rdate

A bitmapped description of a recurring date.

[0]..[3]	monthspec – 1(Jan)..12(Dec), 13-15 is special case
[4]..[15]	<depends on the value of monthspec.

If monthspec = 1-13

[4]..[6]	offset
[7]..[9]	weekday
[10]..[15]	day

If monthspec = 14

[7]..[9]	weekday

If monthspec = 15

[4]..[9]	period
[10]..[15]	delta

monthspec
Specifies a reference month for the holiday

0	Unassigned
1..12	Month of year
13	Action is repeated monthly
14	Action is repeated weekly
15	Action is repeated each **period** referenced by **delta** from the previous Rdate in the table.

Offset
An adjustment to the programmed day for those holidays that track a weekend.

The following values are defined:

[0]	No offset
[1]	Advance to **weekday** before date entered.
[2]	Postpone to the first **weekday** on or after date entered.
[3]	Postpone to the second **weekday** on or after date entered.
[4]	Postpone to the third **weekday** on or after date entered.
[5]	Postpone to the fourth **weekday** on or after date entered.
[6]	Postpone to the last **weekday** of the **month** on or after date entered.
[7]	Observe on date entered as well as day following date entered.
[8]	Postpone to Monday if Sunday.
[9]	Advance to Friday if Sunday.
[10]	Postpone to Monday if Saturday.
[11]	Advance to Friday if Saturday.
[12]	Postpone to Monday if Sunday or Saturday.
[13]	Advance to Friday if Sunday or Saturday.
[14]	Postpone to Monday if Sunday, advance to Friday if Saturday.
[15]	Do not observe date entered. Observe on day following date entered.

weekday
Specifies the day of week if constraint: Sunday(0) to Saturday(6), Unassigned(7)

period
period of repeat for recurring events 0 to 63 days.

delta
delay period 0 to 63 days.

6.3.5.4 Example of Scheduling Component, Schd

The following example of a Schd component describes a simple scheduler that supports on/off control according to a basic 9-5 schedule Monday – Friday. Exceptions to the schedule are the two holidays Christmas and New Years Day.

Component Name	Values Based on Example	Comments
Schd		
|__SchdHdr		
| |__isEdit	TRUE	Can be remotely edited
| |__NumTEV	2	Has 2 TEVs
| |__NumRDat	2	Has 2 Rdat
| |__Sup	{ {0,	{ { bits 0..3: no month of year support

Component Name	Values Based on Example	Comments
|	b'11111',	bits 4..8: supports 24 hours
|	b'1',	bits 9: support for holiday usage
|	b'1',	bit 10: support for holiday mode
|	b'11111',	bits 11..15: full day of month support
|	b'0',	bits 16: no support for one shot events
|	b'0',	bits 17:no support for range protection
|	b'111111'},	bits 18..23: support minute resolution},
|	{b'100'},	{ bits 0..2: simple dow support},
	{0x01},	{supports event values 0..1}
	}	}
|__TimEvts[]	{9:00A any date},{Mon-Fri},1	Set Evt 1 at 9:00A Mon-Fri, except holidays
|	{5:00P any date},{Mon-Fri},0	Set Evt 0 at 5:00P Mon-Fri, except holidays
|__Rdates[]	{12/25}, {1/1}	Holidays dates Christmas and New Years

6.4 Revenue Meter Models

The revenue metering models presented in this section are composed of a translation of the ANSI C12.19 "Tables" performed as part of work in the Customer Interface Working group of the Utilities Communications Architecture Forum[12]. The details presented are a version of this translation. It is noted that the work of the ANSI C12 committee, as well as the corresponding IEEE SCC31 committee, was comprehensive in its description of a model of a revenue meter for electric, gas, and water. It was therefore the goal of the translation to capture the richness of the model accurately. What is presented in this section is a distillation of the translation into the format of the present report with some minor modifications.

The "Tables" embody a data model of meters that is highly compact and optimized for minimal storage and virtually no protocol. For this reason, it is often necessary to acquire the state of many tables to understand the composition of tables containing useful information such as overall consumption.

Tables are numbered and organized into "Decades." Each Decade is further divided into a

zeroth table, such as 0, 10, 20, …

oneth table, such as 1,11,21, …

The zeroth table contains variables that describe maximum limits of the components of the tables of the corresponding decade.

The oneth table contains variables that describe the limits in effect for the components of the tables of the corresponding decade.

The table below is a summary description of the decades modeled in this report.

[12] UCA Forum operated from 1994-1998 under the auspices of the Electric Power Research Institute. Their work is presently being brought under the IEEE SCC36.

Table 6-3: Description of Decades Used in this Report

Decade	Description	Content
Decade 0	Configuration table	**Nameplate and data type information describing the meter.**
Decade 10	Data source tables	Information on the meter's measurements capability
Decade 20	Register tables	measurements made by the meter.
Decade 60	Load Profile tables	time series of measurements. Load profile is critical in analyzing the detailed consumption history observed by the meter

Some components of the tables are not modeled in this section. Decades not modeled are principally omitted because they deal with generic functions that are not meter-specific (although required in an actual device they would be part of other generic models). Those decades not modeled include:

Table 6-4: Description of Decades Not Used in this Report

Decade	Description	Reason
Decade 30	Local Display table	**Should be part of generic user interface model, perhaps customized to metering**
Decade 40	Security tables	Generically handled by UCA 2 in non-meter specific way
Decade 50	Time-of-Use tables	Part of CASM TimeAgent model.
Decade 70	History andeEvent logs	Handled generically as part of CASM reporting and event model
Decade 80	User-defined tables	Not standardized and addressed by CASM DataSets

6.4.1 Meter model

This model is very detailed as a result of more than of 10 years of standards effort by utilities and meter vendors in the ANSI C12.19 and IEEE 1377 standards process. The model is presented in three pieces.

1. First, is the topmost level of the meter model.
2. Second, the versions of the Meter model that are specific to electric, gas, and water revenue metering are presented.
3. In the Appendix is the detailed description of all of the models components with the exception of several structured DataObjects that are re-used several times within the model. Finally, there is a section containing the description of these structured components.

Note that in the description columns of the models in this section there are many elements labeled with a direct reference to the ANSI C12.19 standard as follows showing the table and standard variable name separated by a colon, “:”:

`2:E_FREQ`

Components described in this manner are not elaborated on here but can be found in complete detail in the standard.

6.4.1.1 Top Level ANSI C12.19 based meter model

Simplified ANSI C12.19 based meter model (major structures are shown unexpanded):

Component Name	CLASS	FC	Description
Meter	STRUCT		Meter model
|__Extents	STRUCT	DC	Maximums for programmable meters
|__Cfg	STRUCT	CF	General meter configuration
|__Regs	RegDatRcrd	MX	Meter registers summary table
|__DmdCtl	STRUCT		Demand Control
|__Status	STRUCT	ST	General meter status
|__Cmds	STRUCT		Commands
|__LPCfg	STRUCT		LoadProfile Subsystem configuration
|__LP1	LPTABLE	LG	Load profile table 1
|__LP2	LPTABLE	LG	Load profile table 2
|__LP3	LPTABLE	LG	Load profile table 3
|__LP4	LPTABLE	LG	Load profile table 4
|__PrevSeason	STRUCT	LG	previous season log
|__PrevDmdRst	STRUCT	LG	previous demand reset log
|__SRReg	STRUCT	LG	self read register log
|__Tables	INT8U[ ][ ]		Byte oriented C12.19 table interface
|___…<W, V, A, VAR>	UTILMX		Metered measurements

Extents
Maximum degrees of freedom for meter model.

Cfg
General configuration information about the meter.

Regs
Register data of the meter.

DmdCtl
Demand control and status information.

Status
General status information about the meter.

Cmds
Commands to change the mode of operation of the meter.

LPCfg
Load profile recording subsystem configuration.

LP1
Load profile table 1.

LP2
Load profile table 2.

LP3
Load profile table 3.

LP4
Load profile table 4.

PrevSeason
Snapshot of register information from previous season.

PrevDmdReset
Snapshot of register contents at last demand reset.

SRReg
Self read register log.

Tables
Byte oriented interface to support the reading and writing of ANSI C12.19 tables using full table and partial table with offset and count methods.

… <W, V, A, VAR>
The named measurements of the meter would be found aggregated here.

6.4.2 EMeter Model

The EMeter model inherits the generic Meter model and adds electric meter-specific components. The model by virtue of the construction EMeter:Meter can be presumed to contain all of the components of the Meter model presented in the previous sections plus those specific to electric metering as shown.

Component Name	CLASS	FC	Description
EMeter:Meter	STRUCT		Electric meter model
|__Cfg	STRUCT		Extends the Cfg of meter model
| |__Kh	FLT32	CF	2:E_KH
| |__Kt	FLT32	CF	2:E_KT
| |__Kdiv	INT8U	CF	2:E_INPUT_SCALAR
|__EMRtg	STRUCT	DC	Electric meter equipment rating
| |__Elem	STRUCT		Describes elements
| | |__Hz	EFREQ		2:E_FREQ
| | |__NumElem	ENUM8		2:E_NO_OF_ELEMENTS
| | |__BaseTyp	ENUM8		2:E_BASE_TYPE
| | |__AccCls	ENUM8		2:E_ACCURACY_CLASS
| |__V	STRUCT		Voltage rating
| | |__ClsV	ENUM8		2:E_ELEMENTS_VOLTS
| | |__ExtSupV	ENUM8		2:E_ED_SUPPLY_VOLTS
| |__A	STRUCT		Amperage rating
| | |__ClsA	VSTR6		2:E_CLASS_MAX_AMPS
| | |__TstA	VSTR6		2:E_TA
| |__FrmNum	VSTR5		2:E_ED_CONFIG
|__W	UtilMX		Watt measurement
|__VAR	UtilMX		VAR measurement

EMeter:Meter
The EMeter model inherits from the Meter model and refines it for use in the water industry.

Cfg
The configuration component of the Meter model is extended with these components.

Kh
Watthours per revolution. (May be represented as Unithours per equivalent revolution).

Kt
The commodity amount selected for the test pulse output.

Kdiv
Divisor by which to scale input values. For example if input consists of pulses, a value of 2 would cause the pulse stream to be divided by 2.

EMRtg
Structure describing electric meter ratings.

Elem
Structure describing the elements of the power measurement.

Hz
Power frequency rating code. The codes are::

0	DC
1	25 Hz
2	50
3	50 or 60 Hz
4	60 Hz
5	400 Hz
6	Unassigned
7	Unclassified

NumElem
Number of commodity measuring elements per measuring input to the end device. This code indicates the number of elements as follows:

0	None
1	1 element
2	2 elements
3	2.5 elements
4	3 elements
5	6 elements
6	1.5 elements
7	Unassigned.

BaseTyp
Indicates the type of meter base as follows:

0	None
1	S-base (socket)
2	A-base (ANSI bottom connected)
3	K-base
4	IEC bottom connected
5	Switchboard
6	Rackmount
7	B-base
8	P-base (Canadian Standard)
9-15	Unassigned

AccCls
Reserved for future ANSI solid state meter standard accuracy class definitions.

V
Structure that describes voltage measurement of the meter.

ClsV
Contains binary codes describing meter RMS voltages. Meter element voltage code. This binary code indicates the meter voltage class as follows:

0	None
1	69.3

2	72
3	120
4	208
5	240
6	277
7	480
8	120 thru 277
9	120 thru 480
10-15	Unassigned.

ExtSupV
External supply voltage code. This value identifies the meter supply voltage as follows:

0	Internal
1	69.3 AC
2	72 AC
3	120 AC
4	208 AC
5	240 AC
6	277 AC
7	480 AC
8	120 thru 277 AC
9	120 thru 480 AC
10	48 DC
11	125 DC
12	250 DC
13-15	Unassigned

A
Structure describing the amperage measurements of the meter.

ClsA
End device class or IEC max amp rating.

TstA
The RMS amperage test amps (TA) specified by the manufacturer for the main test and/or adjustment of the meter.

FrmNum
Form number as a string, per ANSI C12.10.

W
The measurement of actual power, in Watts.

VAR
The measurement of real power in VAR.

6.4.3 WMeter Model

The WMeter model inherits the generic Meter model and adds water meter specific components.

Component Name	CLASS	FC	Description
Wmeter:Meter	STRUCT		Water meter
|__WMRtg	STRUCT	DC	Water meter equipment rating
| |__FluidType	FluidTyp		2:W_FLUID_TYPE
| |__Drive	Drive		2:W_ED_DRIVE
| |__PipSz	PipSz		2:W_ED_PIPE_SIZE
|__Water	UltilMX		Water flow measurement

Wmeter:Meter
The WMeter model inherits from the Meter model and refines it for use in the water industry.

WMRtg
Structure describing water meter ratings.

FluidType
Fluid type being metered:

0	Potable water
1	Hot water
2	Non-potable water
3	Sewage primary water
4	Sewage secondary water
5	Sewage tertiary water
6	Other

Drive
Type of drive for meter mechanism:

0	Piston
1	Disc
2	Multi-jet
3	Turbine
4	Compound
5	Propeller
6	Ultra-sonic
7	Magnetic-coupled
8	Differential pressure
9	Mass
10	Variable area
11	Open channel
12	Oscillatory
13	Other

PipSz
Pipe size:

Enum	*PipSz* Description	Enum	*PipSz* Description
1	1/2"	23	34"
2	5/8"	24	36"
3	3/4"	25	40"
4	1"	26	48"
5	1 1/2"	33	13 mm
6	2"	34	15 mm
7	3"	35	20 mm
8	4"	36	25 mm
9	6"	37	40 mm
10	8"	38	50 mm
11	10"	39	80 mm
12	12"	40	100 mm
13	14"	41	160 mm
14	16"	42	200 mm
15	18"	43	250 mm
16	20"	44	300 mm
17	22"	45	350 mm
18	24"	46	400 mm
19	26"	47	450 mm
20	28"	48	500 mm
21	30"	49	600 mm
22	32"	50	800 mm

Water
Water consumption measurement based on the UtilMX model shown in the Appendix.

6.4.4 GMeter Model

The GMeter model inherits the generic Meter model and adds gas meter specific components.

Component Name	CLASS	FC	Description
GMeter:Meter	STRUCT		Measurement
|__GMRtg	STRUCT	DC	Gas meter equipment rating
| |__Form	ENUM8		2:G_MECH_FORM
| |__EngMetric	BOOL		2:G_ENG_METRIC
| |__MaxPress	VSTR16		2:G_MAX_PRESS, G_UOM_PRESS
| |__MaxFlow	VSTR16		2:G_MAX_FLOW, G_UOM_FLOW
| |__GearDrive	VSTR16		2:G_GEAR_DRIVE
| |__IOPipe	ENUM8		2:G_INPUT_OUPUT_PIPE
| |__TempComp	ENUM8		2:G_COMP_TEMP
| |__PressComp	ENUM8		2:G_COMP_PRESS
|__Ngas	UtilMX		Natural gas flow measurement

GMeter:Meter
The GMeter model inherits from the Meter model and refines it for use in the gas industry.

GMRtg
Structure describing gas meter ratings.

Form
Primary mechanical design principle of the device:

0	Unclassified
1	Bellows meter
2	Rotary
3	Turbine meter
4	Fluidic oscillator
5	Anemometer

EngMetric
Boolean to show if the actual measurement is being made in english or metric units. Note that all units of measure in CASM are metric so this flag is only informative as to the underlying principal of the meter.

MaxPress
Maximum pressure rating.

MaxFlow
Maximum flow rating.

GearDrive

0	None
1	1/2'
2	1'
3	2'
4	5'
5	10'
6	100'
7	1000'

IOPipe

Pipe size:

Enum	*PipSz* Description
1	1/2"
2	5/8"
3	3/4"
4	1"
5	1 1/2"
6	2"
7	3"
8	4"
9	6"
10	8"
11	10"
12	12"
13	14"
14	16"
15	18"
16	20"
17	22"
18	24"
19	26"
20	28"
21	30"
22	32"
23	34"
24	36"

Enum	*PipSz* Description
25	40"
26	48"
33	13 mm
34	15 mm
35	20 mm
36	25 mm
37	40 mm
38	50 mm
39	80 mm
40	100 mm
41	160 mm
42	200 mm
43	250 mm
44	300 mm
45	350 mm
46	400 mm
47	450 mm
48	500 mm
49	600 mm
50	800 mm

TempComp

0	Uncompensated
1	Mechanical
2	Sensor

PressComp

0	Uncompensated
1	Mechanical
2	Sensor

Ngas

Natural gas consumption measurement based on the UtilMX model shown in the Appendix.

6.4.5 HMeter Model

The HMeter model inherits the generic Meter model and adds enthalpy meter specific components. Note that this extension is not based on the ANSI C12 model but is a conceptual extension to that work.

Component Name	CLASS	FC	Description
HMeter:Meter	STRUCT		Enthalpy meter
|__HMRtg	STRUCT	DC	Enthalpy meter equipment rating
| |__WkFluid	ENUM8		Working fluid
| |__EMStyle	enum8		Style of enthalpy meter
| |__PipSz	PipSz		2:W_ED_PIPE_SIZE
|__Flux	UltilMX		Enthalpy flux measurement

HMeter
The HMeter model inherits from the Meter model and refines it for use in heat flux measurement applications.

HMRtg
Structure describing enthalpy meter specific ratings.

WkFluid
Fluid type being used to transfer heat:

0	Potable water
1	Hot water
2	Steam
3	Chilled water
4	Non-potable water
5	Sewage primary water
6	Sewage secondary water
7	Sewage tertiary water
…	Others

EMStyle
Type of mechanism for enthalpy measurement:

0	Temperature and flow measurement
1	Peltier
2	…

PipSz
Pipe size:

Enum	*PipSz* Description	23	34"
1	1/2"	Enum	*PipSz* Description
2	5/8"	24	36"
3	3/4"	25	40"
4	1"	26	48"
5	1 1/2"	33	13 mm
6	2"	34	15 mm
7	3"	35	20 mm
8	4"	36	25 mm
9	6"	37	40 mm
10	8"	38	50 mm
11	10"	39	80 mm
12	12"	40	100 mm
13	14"	41	160 mm
14	16"	42	200 mm
15	18"	43	250 mm
16	20"	44	300 mm
17	22"	45	350 mm
18	24"	46	400 mm
19	26"	47	450 mm
20	28"	48	500 mm
21	30"	49	600 mm
22	32"	50	800 mm

Flux
Flux measurement of enthalpy.

6.4.6 Example: Simple Residential Electric Meter

The following is a very simple potential residential electric meter that can only describe its total accumulated measurement of electric consumption. Refer to Appendix: Detailed ANSI C12 meter model for detailed components of the model that are included. This example oversimplifies the possible content of a commercial revenue meter for brevity.

Component Name	**Values Based on Example**	**Comments**
Emeter		
|__Extents		
| |__Cnf	255	Meter configuration set #255 – custom
|__Cfg		
| |__SrcFlgs	0	No source functions for demand control
| |__NumUOMEntry	0	No UOMEntry
| |__NumDmdCtlEntry	0	No demand support
| |__DatCtlLen	0	No data control support
| |__NumDatCtlEntry	0	No data control support
| |__ConstSel	0	One constant
| |__NumSrc	1	One source
| |__RegFuncs	0	No special register functions
| |__NumSlfRead	0	No self read support
| |__NumSumm	0	No summations table support
| |__NumDmd	0	No demand registers
| |__NumCoin	0	No coincident measurements
| |__NumOcc	0	No demand occurrences
| |__NumTiers	0	No tier support
| |__NumPresDmd	0	No present demands
| |__NumPresVal	0	No present values
| |__SummSel	{“EMeter.MX.W.r”}	Only summation is W measurement
|__Status		
| |__Enable	TRUE	Meter is enabled for operation
| |__IEDStatus	0	No bits set – no significant events
|__Cmds		
| |__Enable	--	
| |__Status	--	
|__EMRtg		
| |__Elem		
| | |__Hz	4	enum value for 60 Hz
| | |__NumElem	2	enum value for 2 element
| | |__BaseTyp	1	enum value for S-base (socket)
| | |__AccCls	0	<reserved for future definitions>
| |__V		
| | |__ClsV	3	Element voltage code for 120V
| | |__ExtSupV	3	Meter supply voltage 120VAC
| |__A		
| | |__ClsA	200	200 A rated amps
| | |__TstA	600	600 A Test Amps
| |__FrmNum	“2-S”	Form 2-S meter
|__Cfg		
| |__Kh	1	
| |__Kt	1	
| |__Kdiv	1	

Component Name	Values Based on Example	Comments
|__W		
|__l	1000	Current demand pulses
|__r	9999999	Total pulses
|__s	0.6E0	Scale WH/Pulse

6.5 Quality of Service Models

There are two principal components of quality of service – measurement and annunciation.

In the case of measurement, there is the need to utilize power quality metering devices that can perform analytical measurements of power quality and can record transient events observed on the power line.

Upon detection of a critical transient event, or outright outage, an unsolicited message must be transported upstream to a client for use.

The model presented in this section presumes a generic power-quality monitor (not defined here) capable of measurement of the components of power, and, transient recording of significant events. The monitor generates events detected and causes reports to be generated and sent to a remote client or set of clients.

The work is primarily based on the UCA 2, Customer Interface Working Group, power quality model [EPRI, CIWG, 1997].

6.5.1 PQTrig, Power Quality Trigger

A PQTrig is very much like the description of an oscilloscope trigger. Thus, it has a trigger source, a synchronization source, the type of triggering mode, and a trigger threshold.

Component Name	CLASS	FC	Description
PQTrig	STRUCT	SP	Power quality transient event
|__SyncSrc	IDENT		Source of synch for measurement
|__TrgTyp	ENUM8		Trigger type
|__TrgSrc	IDENT		Source of trigger
|__TrgVal	FLOAT32		Trigger value

<u>SyncSrc</u>
Describes how the monitor sampling is synchronized with the waveform being sampled. The monitored source used for synch is referenced here. The reserved name "INTERNAL" signifies an internal timebase.

<u>TrgTyp</u>
Describes why the event was captured. The allowed values are: HIGHTONORMAL, NORMALTOHIGH.

<u>TrgSrc</u>
Specifies the source that triggered the event.

<u>TrgVal</u>
Specifies the threshold value crossed.

6.5.2 PQEv, Power Quality Transient Event

A power quality event can be thought of as a trace on an oscilloscope. It has a source, a trigger definition, and, some information about the event itself. As with an oscilloscope trace, the waveform measured may not be the same as that which generated the trigger condition.

Because power quality transients can be very short events, they can not be timestamped to a resolution of seconds. To provide for more precise timestamps, a two component timestamp is constructed consisting of seconds and fractional seconds. The primitive DataObject, “tu”, is constructed with the first 4 octets representing seconds since 1/1/84 and the second 4 octets representing fractional seconds.

PQEv is the first model in this report to use the CASM BLOB data type. A discussion of BLOBs is appropriate at this time. Most messaging transporting models in this report require relatively small communications buffers to hold message contents – typically from 50 to 1500 bytes. However, power quality waveform capture may require the transport of very large, of megabyte order, data sets. It is impractical for a communications stack vendor to prepare for the worst case transfer from a GetDataObjectValues, for example, if it could be potentially unlimited in size. Yet such large data sets may realistically need to be transported. Although the size of the data may be large, it may still make logical sense to include such data in an hierarchical model of related information. To reconcile these issues, the BLOB was created in CASM to allow for a thoughtful compromise. When read, the value of a BLOB DataObject is not the data itself, but a reference to it. This visible string, once obtained, can be utilized with the BLOB data transport protocol to fetch its value if desired. The BLOB transport services are very much like a file transfer services in other protocols. For more details on BLOB and BLOB transfer, consult the CASM reference [CASM, 1999].

PQEv is used to define a power quality transient event:

Component Name	CLASS	FC	Description
PQEv	STRUCT	EV	Power quality transient event
|__TypTx	ENUM8		Type of event
|__SeqID	INT32U		Sequence ID to correlate related evts.
|__Nam	IDENT		Name of measurement
|__Mag	FLOAT32		Magnitude of transient
|__StTim	tu		Start time of transient
|__Loc	Loc		Location
|__Polarity	BOOL		Relative polarity of transient
|__Trig	PQTrig		Associated trigger specification
| |__SyncSrc	IDENT		Source of synch for measurement
| |__TrgTyp	ENUM8		Trigger type
| |__TrgSrc	IDENT		Source of trigger
| |__TrgVal	FLOAT32		Trigger value
|__WrstVal	FLOAT32		Worst value observed
|__WrstTim	tu		Time of worst value
|__SpctCont	INT32U		Spectral content
|__PtOnWav	INT32U		Locates the transient relative to 0
|__Dur	INT32U		Duration of transient
|__Wav	BLOB		Waveform

TxTyp
Type of power quality event. (Note that SAGs and SWELLds are PQVariationsLong or PQVariationsShort depending on duration).

[1]	PQTransientsImpulsive
[2]	PQTransientsOscillatory
[3]	PQVariationsShort
[4]	PQVariationsLong
[5]	PQVoltageImbalance
[6]	PQHarmonics
[7]	PQInterharmonics
[8]	PQNotching
[9]	PQNoise
[10]	PQWaveshape
[11]	PQPowerFrequencyVariations
[12]	PQLimitThreshold
[13]	PQTimed

SeqID
Identifies frame to which this event is associated. A frame is a set of events and waveforms that occurred in a contiguous span of time.

Nam
Specifies the reference of the measurement the event occurred on.

Mag
The maximum absolute value the transient reached e.g. peak voltage or current.

StrtTim
Absolute timestamp of transient event.

Loc
User defined identifier that references site specific data.

Polarity
Contains the direction of the impulse with respect to the instantaneous value of the parameter being measure just before the impulse occurred. For instance if the instantaneous voltage just before the event was -100 volts and the maximum excursion voltage is +10 volts then polarity is negative. The allowed values are positive = TRUE, and negative = FALSE.

Trig
Contains the trigger specification used to generate the transient capture.

SyncSrc
Describes how the monitor sampling is synchronized with the waveform being sampled. The monitored source used for synch is referenced here. The reserved name “INTERNAL” signifies an internal timebase.

TrgTyp
Describes why the event was captured. The allowed values are: HIGHTONORMAL, NORMALTOHIGH

TrgSrc
Specifies the source that triggered the event.

TrgVal
Specifies the threshold value crossed.

WrstVal
Extreme value measured.

WrstTim
Timestamp of extreme value.

Spctcont
Rise time in nanoseconds of the leading edge.

PtOnWav
Time in fractional seconds from last previous positive zero crossing to peak value.

Dur
Width in nanoseconds of entire transient.

Wav
BLOB representing the actual waveform data itself.

6.5.2.1 Example

The following example is a positive going transient impulse measured by a power quality qualified electric meter. In the example, 1.2KV transient is detected on the voltage phase of an electric meter. The trigger specification associated with the transient was not transported in this example.

Component Name	**Values Based on Example**	**Comments**
PQEv		
|__TypTx	1	PQTransientsImpulsive
|__SeqID	-1	Default value
|__Nam	M0002/EMeter.MX.V	The voltage measurement of meter
|__Mag	1.2E3	1.2 KV
|__StTim	12/31/98, 5:00:03.1234	
|__Loc	1.2.99.3.4.5.6.734667	Identifies point of measurment
|__Polarity	TRUE	Positive going transient
|__SpctCont	100	Rise time of 100ns
|__PtOnWav	0.0043333	4 msec into start of positive going cycle
|__Dur	0.10234	0.1 seconds
|__Wav	A	Stored in buffer 'A', retrieve using this reference and the BLOB transfer protocol.

6.5.3 PQM Power Quality Monitor

The PQM model contains triggers, transient events recorded, and, some descriptive information of the size of these sets.

Component Name	CLASS	**FC**	**Description**
PQM	STRUCT		Power quality monitor
|__NumEvts	INT16U	CF	Number of PQEvts stored
|__NumTrgs	INT16U	CF	Number of PQTrig supported
|__PQEvts	PQEv [ ]	EV	Power quality transient events
|__Trgs	PQTrig [ ]	SP	Trigger descriptions
|__ClrAllEvt	BOOL	CO	Clear all events
|__Rpt	RCB	RP	Reporting description
|__Evt	DS	DS	Data set containing report components

NumEvts
Number of Pqevts occured.

NumTrgs
Maximum number of triggers that establishes a power event.

PQEvts
Array of events stored.

Trgs
Array of trigger descriptions.

ClrAllEvt
Clears all current events.

Rpt
Description of reports to be generated.

Evt
DataSet definition for report generation.

6.6 Tariff Model

The core of this DataObject model is derived from UCA, Customer Interface Working Group (CIWG) data modeling activities and has been modified to satisfy a wide range of RTP tariffs and rate schedules [EPRI, CIWG, 1997]. This model also incorporates work done in conjunction with the development of ANSI C12.22 [ANSI C12.22a].

The Tariff DataObject is designed to support varied methods of pricing and schedule distribution such as hourly RTP, as well as traditional time-of-use and constant rate schedules. The Tariff data model is presented below.

Component Name	**CLASS**	**FC**	**Description**
Tariff	STRUCT		Contains tariff for RTP
|__ID	OBJID	DC	Identifies tariff
|__NumMx	INT8U	DC	Number of measurements
|__d	d	DC	Description of tariff
|__BillToDat	FLT32	ST	Bill to date for current billing period
|__curr	ENUM16	DC	Currency
|__Cmps[]	STRUCT[]		Components of tariff
|__Pricing	STRUCT		Pricing subcomponent
| |__CurPrice	FLT32	ST	Current price
| |__CurTier	INT8S	ST	Current tier
| |__Nam	VSTR32	DC	Describes measurement
| |__Typ	ENUM8	DC	Type of pricing
| |__u	U	DC	Units of measurement
| |__NumBins	INT16U	CF	Number of bins
| |__Prices[]	FLT32	SP	Prices per bin
| |__Scale	FLT32	CF	Scale of counts in bins
| |__Bins[]	INT32S	SP	Accumulated values
|__RefProfile	STRUCT		Reference profile
| |__NumIntv	INT16U	SP	Number of intervals
| |__DelT	INT16U	SP	Time between intervals
| |__Counts[]	INT32S	SP	Reference profile counts
|__Schd	STRUCT		Scheduling of tier change
|__NumSchd	INT16U	DC	Number of elements
|__Schds[]	Schd[]	SP	Schedule elements
|__EditMode	BOOL	CF	Enable/disable edit
|__AddEntry	Schd	CO	Write to add an entry

Tariff
Tariff describes a complete structure by which a utility bill may be constructed.

ID
A globally unique identifier of this Tariff object.

NumMx
Number of measurements in the Tariff that comprise the billable commodities.

d
Brief description of Tariff.

BillToDat
A sum of the bill to date for the current billing period.

curr
Base currency (currency of accountability for Tariff.

Base currency for Tariff. Currency specified by ISO 4217. [ISO 4217,1995] below (Note that Euro has not been assigned by the standard and is given a temporary value of 255):

No.	Currency
1	Andorran Peseta
2	United Arab Emirates Dirham
3	Afghanistan Afghani
4	Albanian Lek
5	Netherlands Antillian Guilder
6	Angolan Kwanza
7	Argentinian Austral
8	Austrian Schilling
9	Australian Dollar
10	Aruban Florin
11	Barbados Dollar
12	Bangladeshi Taka
13	Belgian Franc
14	Bulgarian Lev
15	Bahraini Dinar
16	Burundi Franc
17	Bermudian Dollar
18	Brunei Dollar
19	Bolivian Boliviano
20	Brazilian Cruzeiro
21	Bahamian Dollar
22	Bhutan Ngultrum
23	Burma Kyat
24	Botswanian Pula
25	Belize Dollar
26	Canadian Dollar
27	Swiss Franc
28	Chilean Unidades de Fomento
29	Chilean Peso
30	Yuan (Chinese) Renminbi
31	Colombian Peso
32	Costa Rican Colon

No.	Currency
33	Czech Koruna
34	Cuban Peso
35	Cape Verde Escudo
36	Cyprus Pound
37	East German Mark (DDR)
38	Deutsche Mark
39	Djibouti Franc
40	Danish Krone
41	Dominican Peso
42	Algerian Dinar
43	Ecuador Sucre
44	Egyptian Pound
45	Spanish Peseta
46	Ethiopian Birr
47	Finnish Markka
48	Fiji Dollar
49	Falkland Islands Pound
50	French Franc
51	British Pound
52	Ghanaian Cedi
53	Gibraltar Pound
54	Gambian Dalasi
55	Guinea Franc
56	Greek Drachma
57	Guatemalan Quetzal
58	Guinea-Bissau Peso
59	Guyanan Dollar
60	Hong Kong Dollar
61	Honduran Lempira
62	Haitian Gourde
63	Hungarian Forint
64	Indonesian Rupiah

No.	Currency
65	Irish Punt
66	Israeli Shekel
67	Indian Rupee
68	Iraqi Dinar
69	Iranian Rial
70	Iceland Krona
71	Italian Lira
72	Jamaican Dollar
73	Jordanian Dinar
74	Japanese Yen
75	Kenyan Schilling
76	Kampuchean (Cambodian) Riel
77	Comoros Franc
78	North Korean Won
79	South Korean Won
80	Kuwaiti Dinar
81	Cayman Islands Dollar
82	Lao Kip
83	Lebanese Pound
84	Sri Lanka Rupee
85	Liberian Dollar
86	Lesotho Loti
87	Luxembourg Franc
88	Libyan Dinar
89	Moroccan Dirham
90	Malagasy Franc
91	Mongolian Tugrik
92	Macau Pataca
93	Mauritanian Ouguiya
94	Maltese Lira
95	Mauritius Rupee
96	Maldive Rufiyaa
97	Malawi Kwacha
98	Mexican Peso
99	Malaysian Ringgit
100	Mozambique Metical
101	Nigerian Naira
102	Nicaraguan Cordoba
103	Dutch Guilder
104	Norwegian Kroner
105	Nepalese Rupee
106	New Zealand Dollar
107	Omani Rial
108	Panamanian Balboa
109	Peruvian Inti
110	Papua New Guinea Kina

No.	Currency
111	Philippine Peso
112	Pakistan Rupee
113	Polish Zloty
114	Portuguese Escudo
115	Paraguay Guarani
116	Qatari Rial
117	Romanian Leu
118	Rwanda Franc
119	Saudi Arabian Riyal
120	Solomon Islands Dollar
121	Seychelles Rupee
122	Sudanese Pound
123	Swedish Krona
124	Singapore Dollar
125	St. Helena Pound
126	Sierra Leone Leone
127	Somali Schilling
128	Suriname Guilder
129	Sao Tome and Principe Dobra
130	USSR Rouble
131	El Salvador Colon
132	Syrian Potmd
133	Swaziland Lilangeni
134	Thai Bhat
135	Tunisian Dinar
136	Tongan Pa'anga
137	East Timor Escudo
138	Turkish Lira
139	Trinidad and Tobago Dollar
140	Taiwan Dollar
141	Tanzanian Schilling
142	Uganda Shilling
143	US Dollar
144	Uruguayan Peso
145	Venezualan Bolivar
146	Vietnamese Dong
147	Vanuatu Vatu
148	Samoan Tala
149	Democratic Yemeni Dinar
150	Yemeni Rial
151	New Yugoslavia Dinar
152	South African Rand
153	Zambian Kwacha
154	Zaire Zaire
155	Zimbabwe Dollar
255	Euro

Cmps[]
An array of components of the Tariff. One component is present for each measurement based charge.

Pricing
Contains pricing information for the Cmps that contains it.

CurPrice
The current value of the price contribution of the Cmps[] that it is in.

CurTier
The current index into the array of prices used to value the quantity accumulating in the bins.

Nam
Measurement description. E.g., "Emeter.MX.W.r" for cumulative watt-hours. Use CASM measurement naming convention.

Typ
Type of billing basis.

[1]	Accumulated values
[2]	Maximum or peak value
[3]	Minimum value
[4]	Differential values relative to reference profile
[5]	Quarter hour accumulated values
[6]	Hourly accumulated values
[7]	Monthly accumulated values

u
Units of measure for measurement. See CASM definitions for "u."

NumBins
Number of bins and prices.

Prices[]
Array of prices for each tier. Each price corresponds to a bin of the same index.

Scale
Scale of measurement counts recorded in bins.

Bins[]
Array of recorded measured commodities for which a charge is to be accumulated.

RefProfile
Contains a reference load profile against which comparisons can be made.

NumIntv
Number of intervals in reference profile.

DelT
Number of minutes between intervals in reference profile.

Counts[]
Individual counts for each interval. Units of each count are the same as defined in the pricing component.

Schd
Schedules for the Tariff component.

NumSchd
Number of schedules present.

Schds[]
Array of schedule "statements" that describe a change to a given tier.

EditMode

A flag that is set to TRUE to enable additions to the schedule list.

AddEntry

A new Schd is written here to be added to the Schds array. The use of this mechanism facilitates writing the Schds array in part rather than in total.

6.6.1 Generation of Bills

The Tariff model supports the distribution of billing information so that customers can dynamically produce estimated (although unofficial) bills that can be used in an energy management strategy. The estimated bill can be computed from the Tariff data structure for each tier-based component as follows (for the j^{th} component):

$$TARIFF.Cmps[j].\Pr icing.Cur\Pr ice = \sum_{i=0}^{NumBins-1} (\mathrm{Prices[i]} * \mathrm{TARIFF.curr}) * (\mathrm{Bin[i]} * \mathrm{Scale}) \qquad (2)$$

This computation would be repeated for each "Cmps" in the Tariff to allow contributions from several measurement categories such as demand and consumption.

$$TARIFF.BillToDat = \sum_{j=0}^{NumMx-1} Cmps[j].\Pr icing.Cur\Pr ice \qquad (3)$$

6.6.2 Example of an RTP Tariff

The example is based on Pacific Gas and Electric Company's experimental real-time pricing service, Schedule A-RTP [PG&E, SCHEDULE A-RTP, 1998]. The rate schedule is summarized as follows:

1. RTP customer charge (per meter per month) (E-19 Primary)[13] $415.00
2. RTP demand charge (per kW of max. demand over 1 month) $2.55
3. RTP base rate (per kWh) $0.00346
4. RTP variable rate (per kWh), disagregated into 24 hourly values variable

The variable hourly rate is fictitiously chosen to be:

Hour/tier	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
¢/kWh	2.41	2.33	2.14	2.14	2.15	2.37	2.77	3.39	3.78	4.09	4.18	4.45
Hour/tier	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
¢/kWh	4.40	4.72	4.68	4.29	3.88	4.19	4.61	4.40	3.74	3.18	2.75	2.70

- Prior to 16:00 hour each day, PG&E provides customers with prices valid from midnight to midnight the following day. Updates are possible after 16:00 hour, but limited to maximum of 70 hours per year.
- For bundled service customers, monthly bills are calculated as if the customers were still on their regular rate schedule (E-19) for the energy charge. The difference between the amount due under the regular schedule and the amount due under real-time pricing will be credited or debited on the hourly bases.

[13] Schedule A-RTP has several RTP customer charges: (1) E-19 Primary; (2) E-19 Secondary; (3) E-20 Primary; (4) E-20 Secondary. We chose arbitrarily E-19 Primary.

An instance of the Tariff model for the PG&E's RTP schedule for a regular notification (prior to 16:00 hour) is shown below.

Component Name	**Values Based on Example**	**Comments**
Tariff		
|__ID	1.2.3.4.555.666	ObjectID for example tariff 121198
|__NumMx	4	4 components of the tariff
|__d	"A-RTP (E-19P)"	Name of rate schedule
|__BillToDat	1.234567E3	Bill to date of 1234.567USD
|__curr	143	$USD
|__Cmps[0]		**Customer Charge**
| |__Pricing		
| |__CurPrice	415.00	$415.00/meter
| |__Nam	"M0002/EMeter"	For whole meter
| |__Typ	7	Represents value associated over 1 month
|__Cmps[1]		**Demand Charge component.**
| |__Pricing		
| |__Nam	"M0002/Emeter.MX.W.i"	Measurement in W
| |__Typ	2	Represents maximum or peak value
| |__NumBins	1	One bin
| |__Prices[]	0.00255	Price per peak W
| |__Scale	1.00	1 W per pulse
| |__Bins[]	<>	Actual pulse or count data
|__Cmps[2]		**RTP Base rate**
| |__Pricing		
| |__Nam	"M0002/Emeter.MX.W.r"	Measurement in Wh
| |__Typ	7	Value associated over 1 month
| |__NumBins	1	One bin
| |__Prices[]	3.46E-6	Price per Wh
| |__Scale	1.00	1 WH per pulse
| |__Bins[]	<>	Actual pulse or count data
|__Cmps[3]		**Variable energy charge**
|__Pricing		
| |__CurPrice	2.15E-5	$.0215/KWh
| |__CurTier	4	
| |__MxNam	"M0002/Emeter.MX.W.r"	Measurement in Wh
| |__Typ	6	Represents accumulated hourly values
| |__NumBins	24	One bin for each hour
| |__Prices[]	0.0241,0.0233,0.0214,0.0214,0.0215,0.0237,0.0277,0.0339,0.0378,0.0409,0.0418,0.0445,0.044,0.0472,0.0468,0.0429,0.0388,0.0419,0.0461,0.044,0.0374,0.0318,0.0275,0.027	Array of 24 hourly price data in USD
| |__Scale	1.00	1 WH per pulse
| |__Bins[]	<>	Actual pulse or count data
|__Schd		
|__NumSchd	24	One schedule 1st to last of the month
|__Schds[]	01011999@00:00,1 01011999@01:00,2 01011999@02:00,3 01011999@03:00,4	Starting date and time of a period in schedule Times and tier. Note schedule shows hourly tier changes but is not limited to this.

Component Name	**Values Based on Example**	**Comments**
	………………….. 01011999@21:00,21 01011999@22:00,22 01011999@23:00,23	

6.7 Load Management Models

6.7.1 Remote Load Management Model

The remote-load-management model, RmtMgmt, provides for a supervisory control mechanism for an arbitrary device or subsystem. It is meant to allow for generic control of virtually anything by mutual agreement by the controller and the controlled. This model has been devised by the authors for this report.

The RmtMgmt model supports sets of parameters to some device-internal algorithm. When a client needs to provide for remote management, it can invoke the desired set of parameters based on the currently selected index into the table of parameter sets, CurLvl.

A possible application would have the CurLvl component set as a result of a tier change in some complex rate structure. The device or subsystem containing the RmtMgmt model could then control based on the tier in effect. To support local override and accounting for overrides, the model contains counts of override events, as well as, total runtime and runtime in override.

Component Name	**CLASS**	**FC**	**Description**
RmtMgmt	STRUCT		Remote management component
|__NumParms	INT8U	CF	Number of parameter per level
|__NumLvl	INT8U	CF	Number of levels
|__CurLvl	INT8U	ST	Current level
|__CurParms	FLT32 [ ]	ST	Currently used parameters
|__Schd	Schd	SP	Scheduling of transitions
|__Parms	FLT32 [ ] [ ]	CF	Stored parameter sets
|__NumOcc	INT16U	ST	Occurrences of changes
|__NumOvr	INT16U	ST	Number of overrides
|__Rand	INT8U	CF	Randomize schedule times
|__RT	BTIME6	ST	Total runtime
|__RTOvr	BTIME6	ST	Runtime override

NumParms
Number of parameters per level.

NumLvl
Number of levels defined.

CurLvl
The current level and set of parameters loaded.

CurParms
The current parameters used for control by the device.

Schd
Schd that describes the changes in the current paramteers. The Evt code for the TimEvts represent the selected value of the set of Parms to be set into use.

Parms
An array of sets of parameters to be used to control the device. In essence, these represent a set of supervisory setpoints to be used by the control algorithms of the device. The elements of the arrays are all dimensionless floating point numbers which can be interpreted by prior agreement between the supervisory controller and the management of the field devices to be controlled.

NumOcc
Number of occurrences of change in the CurParms due to scheduled or direct overrides to the CurLvl component.

NumOvr
Number of overrides of the operating parameters affected by the device owner. This statistic can be used in a monitoring regime that might permit, for example, “x” overrides per billing period.

Rand
Randomize the scheduled transition times by a number of minutes between zero and this value. The purpose of the randomization parameter is to spread transitions over a period of time to minimize large discontinuities in the consumption of a utility due to synchronization of scheduled transitions over a wide area.

RT
Run time of the managed device.

RTOvr
Total run time during local override conditions.

6.7.1.1 Example of the RmtMgmt Model

For this example, assume that a contract has been devised that has strict limits on demand and harmonic interference, but only during certain critical times. In this case, it is desired that the peak consumption and the power factor be controlled according to Table 6-5 below.

It might be permissible under the above constraints to violate them for two periods per billing period using some locally available override. The commercial entity managing the remote management could audit the process by reading the override information in the model.

Table 6-5: Example for a Load Management Directive

Schedule	Peak Maximum	Power Factor
9:00A to 5:00P Mon-Fri	100 KW	95%
5:00P to 0:00A Mon-Fri	140 KW	90%
Sat-Sun	180 KW	88%
Holidays Xmas and New Years Day	180 KW	88%

The RmtMgmt mode for this load directive is listed below.

Component Name	**Values Based on Example**	**Comments**
RmtMgmt		
|__NumParms	2	2 parameters Peak and Power factor
|__NumLvl	3	3 Levels
|__CurLvl	0	Current level is level 0
|__CurParms	{1.0E5,9.5E-1}	Daily operating coditions
|__Schd	***	*** See below
|__Parms | |	{1.0E5,9.5E-1}, {1.4E5,9.0E-1}, {1.8E5,8.8E-1}	9:00 to 5:00 5:00 to 0:00 Sat/Sun and Holidays
|__NumOcc	1472	Been running a while
|__NumOvr	4	4 customer overrides to date
|__Rand	15	Randomization of transitions over 15 mins
|__RT	10000000,368	total runtime in milliseconds and days
|__RTOvr	2450,22	total override runtime in milliseconds/days

*** for ease of reading, the components of Schd is as follows:

Component Name	**Values Based on Example**	**Comments**
Schd		
|__SchdHdr		
| |__IsEdit	TRUE	Can be remotely edited
| |__NumTEV	4	Has 4 TimEvts
| |__NumRDat	2	Has 2 Rdates

| |__Sup
|
|
|
|
|
|
|
|
|
	{
	{0,
	b'11111',
	b'1',
	b'1',
	b'11111',
	b'0',
	b'0',
	b'111111'},
	{b'100'},
	{0x01},
	}
		{
		{ bits 0..3: no month of year support
		bits 4..8: supports 24 hours
		bits 9: support for holiday usage
		bit 10: support for holiday mode
		bits 11..15: full day of month support
		bits 16: no support for one shot events
		bits 17:no support for range protection
		bits 18..23: support minute resolution},
		{ bits 0..2: simple dow support},
		{supports event values 0..1}
		}

|__TimEvts[] | | | |	{9:00A any date},{Mon-Fri},0 {5:00P any date},{Mon-Fri},1 {0:00P any date},{Mon-Fri},2 {any time any date on holiday},{any day},2	Set Evt 0 at 9:00A Mon-Fri, except holidays Set Evt 1 at 5:00P Mon-Fri, except holidays Set Evt 2 at 0:00A Mon-Fri, except holidays Set Evt 2 on holidays
|__Rdates[]	{12/25}, {1/1}	Holidays dates are Christmas and New Years

6.7.2 Direct Load Control Model

The direct load control model, DLC, is derived primarily from the UCA, Customer Interface Working Group (CIWG) [EPRI, CIWG, 1997]. It is designed to generically express the need for a reduction of consumption of the capacity of the device in which it is installed. By not requiring specific knowledge of the nature of the device that must interpret it, a single simple model can be used. It is up to the knowledge and creativity of the manufacturer how to implement a desired request for reduction based on the specifics of the product.

For instance, assume a 20% load reduction is issued to a residential air-conditioner (AC) system controller for the time period between 2:00 p.m. and 7:00 p.m.. The controller will need to devise a control strategy that is specific for the particular AC system. For a variable-speed drive system, the controller would request modulation to a lower motor speed such that 20% demand reduction is achieved. A constant speed system would need to be cycled on and off such that the average demand over the time period is reduced by the reduction target.

Component Name	**CLASS**	**FC**	**Description**
DLC	STRUCT	CO	Contains direct load control
|__PctFullDty	INT8U	CO	Percent of full duty cycle to operate
|__DtyWnd	INT16U	CO	Time interval to achieve average
|__DtyDur	INT16U	CO	Duration of this command
|__StartTim	BTIME6	CO	Start time for this command
|__Rand	INT8U	CO	Randomize start by this amount

<u>PctFullDty</u>
Percentage of full duty cycle to attenuate consumption.

<u>DtyWnd</u>
Time window over which the PctFullDty cycle is to be realized. The load can decided whether this is accomplished via cycling or reduced capacity, etc.. This figure is given in minutes.

<u>DtyDur</u>
The total duration of this direct load control command as measured from the StartTim (not the randomized adjustment).

<u>StartTim*</u>
Start time for this direct load control command.

<u>Rand</u>
A number of minutes to randomize the start time. A value of 0 means no randomization. A number greater than zero implies that a random number from zero to that value is added to start time to determine actual start time. Note that this implies start times of always greater than or equal to StartTim.

**Note: StartTim randomization is proposed to mitigate sharp drops in the load at the time when the load reduction request is executed by many customers. Discontinuities in the load may cause stability problems and are, therefore, to be avoided or minimized.*

6.7.3 Example of DLC Model

Assume a residential customer has an agreement with the utility company to permit the utility to reduce the electrical demand of the AC system during the summer for a time period up 4 hours at a time. The utility decides to request a 70% load reduction from all subscribing participants during the time period between 4:00 p.m. and 7:00 p.m.. The DLC data object shown below supports the control directive of this example.

Component Name	**Values Based on Example**	**Comments**
DLC		
|__PctFullDty	70	Reduce consumption to 70% of max
|__DtyWnd	30	70% is average over 30 minutes
|__DtyDur	180	Perform reduction for 3 hours
|__StartTim	10:00	Start at 10:00 Greenwich Mean Time (GMT)
|__Rand	15	Add 0-15 minutes to start time

The averaging period is specified to be 30 min. allowing constant speed AC system to cycle on and off such that the average over 30 min. must meet a 70% reduction compared to continuous operation. To meet the 30 min. reduction target, the system must be 21 min. idle and operate for 9 min. To spread out the onset of this load reduction measure, the control device can chose a random start time within a 15-min. window.

6.8 On-Site Generation Models

The on-site generation models support the remote management of utility connected customer or third party owned generation equipment such as co-generation, fuel cells, and free standing generators. On-site generation comprises three modeling components:

1. Measurements at customer site (e.g., voltage, current, power, power factor)
2. Utility and premise protective relaying to separate generator from grid (e.g., IEEE relay functions 81, 27, 59, 32, 25, 50, and 51 [IEEE Std. 37.2])
3. Remote supervisory management of on-site equipment

The on-site generation models were derived primarily from GOMSFE (see [EPRI, GOMSFE, 1999] for measurements and utility protective functions). The final component of supervisory management was developed for this report.

6.8.1 Measurements

The measurements are represented using instances of the AI model described in Section 0. Related measurements are grouped into two classes to represent common configurations of AC phases in electrical services. Proposed are two groups of measurements that sufficiently express the electric properties at the generator. The two groups are represented by the WYE and the DELTA data model. They are described below.

Component Name	**CLASS**	**FC**	**Description**
WYE	STRUCT		WYE power service
|__PhsA	AI		Phase A
|__PhsB	AI		Phase B
|__PhsC	AI		Phase C
|__PhsN	AI		Phase N

WYE
Wye connected three-phase electric service.

PhsA
The "A" electrical phase measurement.

PhsB
The "B" electrical phase measurement.

PhsC
The "C" electrical phase measurement.

PhsN
The "N" electrical phase measurement (neutral).

Component Name	CLASS	FC	Description
DELTA	STRUCT		DELTA power service
|__PhsAB	AI		Phase AB
|__PhsBC	AI		Phase BC
|__PhsCA	AI		Phase CA

DELTA
DELTA connected three-phase electric service.

PhsAB
The "AB" electrical phase measurement between phase A and B.

PhsBC
The "BC" electrical phase measurement.

PhsCA
The "CA" electrical phase measurement.

The following are the models of measurements for utility protective function monitoring that would be appropriate in on-site generation equipment:

Object Name	Class	Description
V	WYE	Voltage on phase A, B, C to G
PPV	DELTA	Voltage AB, BC, CA
A	WYE	Current in phase A, B, C, and N
W	WYE	Watts in phase A, B, C
TotW	AI	Total watts in all three phases.
VAr	WYE	VArs in phase A, B, C
TotVAr	AI	Total VArs in all three phases.
VA	WYE	VA in phase A, B, C
TotVA	AI	Total VA in all three phases.
PF	WYE	Power factor for phase A, B, C
AvgPF	AI	Average power factor of all three phases.
Ang	WYE	Angle between phase voltage and current
Hz	AI	Power system frequency
FltMagA	WYE	Fault magnitude in phase A, B, C, N
…	…	Other measurements

GOMSFE is currently working on data object models for single-phase applications [EPRI, GOMSFE, 1999]. In order to avoid duplicate modeling efforts, it is suggested to wait for the completion of GOMSFE's modeling results. GOMSFE's results will be assessed and, if necessary, modified to fit this modeling framework. It is expected that GOMSFE will finalize the models in 1999.

6.8.2 Protective Relaying Functions

For bilateral protection of the utility grid and generator, a set of relays are installed, which are designed to trip at specific thresholds and events to separate the generator from the utility grid. The following data models describe the measurements necessary for monitoring the utility protective function for the on-site generator.

The protective relaying functions have been extensively modeled in GOMSFE [EPRI, GOMSFE, 1999]. The following table summarizes the GOMSFE protective relaying components:

GOMSFE Model NAME	Device Function	IEEE Std 37.2 Device Function #
PBRO	Basic Relay Object (building block)	
PBTC	Basic Time Curve Object (building block)	
PDIS	Distance	21
PVPH	Volts Per Hz Relay	24
RSYN	Synchronizing or Synchronism-Check	25
PUVR	Undervoltage Relay	27
PDPR	Directional Power Relay	32
PUCP	Under Current or Under Power	37
PBRL	Reverse Phase or Phase Balance Current Relay	46
PTTR	Machine or Transformer Thermal Relay	49
PIOC	Instantaneous Overcurrent	50
PTOC	Time Overcurrent	51
PFRL	Power Factor Relay	55
POVR	Overvoltage	59
PVCB	Voltage or Current Balance Relay	60
PHIZ	Ground Detector	64 HiZ
PDOC	Directional Overcurrent	67
PPAM	Phase Angle Measuring Relay	78
RREC	Reclosing Relay	79
PFRQ	Frequency	81
RCPW	Carrier or Pilot-Wire Relay	85
PDIF	Differential	87

6.8.3 Supervisory Control and Monitoring Functions

Supervisory control determines the overall operation of the one or more generators. The control privileges can be transferred by the on-site operator to a third party (i.e., utility or service provider) for remote operation. The on-site operator typically retains the option to remove control privilege from the third party in cases of emergencies and power outages on-site. Except for the control transfer, both the third party and on-site operator have the same control capabilities. The following is a sufficient set of control parameters:

- On/off switch of the generator
- Schedule for availability of control by third party
- Load management functions that specify the operational mode (e.g. baseload operation versus load-following and load sharing in case for several generators).
- Export of electric power into the grid
- Selecting and setting limit (upper and lower) values for tripping utility protective relays for load breaker and transformer.
- Specifying monitoring functions and logging reports.

The monitoring functions are grouped into generator and prime mover (engine) class. The generator class consists of measurements partially captured in the WYE and DELTA model. Those original raw measurements are processed to represent the following properties:

- W
- VA
- VAR
- Power Factor
- Voltage
- Cumulative watt-hour (Wh)
- Harmonics.

For internal combustion engine as the prime mover, typically the following engine properties are monitored:

- Engine cumulative run-hours
- Coolant temperature
- Oil pressure
- Engine speed
- Fuel consumption.

There may be other system parameters to be monitored for non-conventional generation technologies such as fuel cells.

This section derives two new models for the purposes of managing remote devices – SYSMON, and, SPVSGEN.

SYSMON supports the remote monitoring of devices associated with a particular on-site generation system. Measurements are collected and presented as a group.

SPVSGEN supports the supervisory control of the remote generation source.

6.8.3.1 SYSMON Model

This data model SYSMON is defined below.

Component Name	CLASS	FC	Description
SYSMON	STRUCT		System monitoring
|__Name	VSTR32	DC	System name
|__NumMx	INT8U	DC	Number of system parameters
|__Comp[]	AI [ ]		Measurments

<u>Name</u>
System name.

<u>NumMx</u>
Number of subsystems to drive generator or enable the generator of electricity.

<u>Comp</u>
Array of subsystem component measurements – e.g., coolant temperature, oil temperature, engine speed, etc. Note that critical limits hl and ll are probably present.

6.8.3.2 SPVSGEN Model

The SPVSGEN model represents the supervisory control functionality for the on-site generator.

Component Name	CLASS	FC	Description
SPVSGEN	STRUCT		Supervisory control
|__ID	OBJID	DC	Identifies site
|__Numgen	INT8U	DC	Number of generators
|__KWAvail	FLT32	DC	Currently available capacity on site
|__ThirPtID	VSTR32	DC	Third party ID (EIA)
|__ThirPtNam	VSTR32	DC	Third party name
|__Gen	STRUCT [ ]		Array of generator information
|__On	BOOLEAN	ST	Status flag for prime mover.
|__RmRT	INT32U	ST	Remaining avail hours of run-time
|__Avail	Schd		Schedule of availability
|__OpMod	ENUM8	ST	Operational Mode
|__Expt	BOOLEAN	CF	Allow export of electricity
|__PrRl	IDENT [ ]	AS	Protective relaying data
|__CumHr	INT32U	ST	Cumulative run-hours
|__CumHrTl	INT32U	ST	Cumulative
|__Mon	SYSMON		Engine monitoring

<u>ID</u>
Identification of site on which generator is located.

<u>Numgen</u>
Number of generators at site.

<u>KWAvail</u>
Currently available generator capacity in [kW]. This can include multiple generator stations.

<u>ThirPtID</u>
Third party identification. Third party is the entity with whom the owner shares control and dispatch privileges.

<u>ThirPtNam</u>
Name of third party.

<u>Gen</u>
Array of control, protective relaying, and monitoring information.

<u>On</u>
Operational status flag. Switch from <u>True</u> to <u>False</u> turns generator off. Switch from <u>False</u> to <u>True</u> turns generator on.

<u>True:</u> Currently running

<u>False:</u> Currently not running

<u>RmRt</u>
Remaining runtime in hours. Contractual agreements may limit the total cumulative number of hours to operated during a 1 year period. For instance, for diesel fuel internal combustion engines, local air emission standards may limit the total number of runtime per year.

<u>Avail</u>
Availability schedule. This variable is a structured variable of class ‘sched’ as described in earlier chapters. The schedule indicates scheduled maintenance or other down time during which the generator is not available for remote control.

OpMod

Load management or operational mode. The generator can be operated in the following modes:

3	baseload
4	load following

Expt

In case, the generation exceeds the load, the 'Expt' flag indicates if electric power is exported into the utility grid.

PrRl

Protective relaying measurements and threshold values are incorporated by reference here.

CumHr

Cumulative hours of operation under third party since Jan. 1 of each year or the earliest , beginning the first day of contractual agreement.

CumHrTl

Total number of generator's runtime.

Mon

Monitoring data class expressing measurements and limit values within which the engine is operated. Because the multitude of different prime movers and generation systems (systems without prime movers such as fuel cells), a new data model class is proposed designed to express measurements and limits in general terms.

6.8.4 Example of On-Site Generator Control

Assume a diesel generator rated at 250 kW for 110 V AC service and is equipped with paralleling switchgear. The utility has an contractual agreement with the owner of the generator to assume control up to 250 hours per year. The control of the generator is established via the on-site BAS using two-way communications.

The specificity of modern relaying and protective technology has evolved to a point where large microprocessors and extensive digital signal processing have been utilized to analyze for disruptions and transient events. For this reason, the models expressed by GOMSFE are quite extensive as developed by the vendors of these devices. Therefore, the details of measurements and protective functions are omitted from the example detail to allow clarity in the presentation of the components of interest to third party applications.

The following control parameters are available to the utility:

- On/off switch of the generator
- Setting and monitoring the following generator protective relays numbered:

  81: Frequency protection, PFRQ
  27: Undervoltage relay, PUVR
  59: Overvoltage relay, POVR
  32: Directional power relay, PDPR
  25: Synchronization check, RSYN
  50: Instantaneous overcurrent, PIOC
  51: Time overcurrent, PTOC

- Operational mode control. Utility chooses baseload mode.

The diesel engine is monitored using the following parameters:

- Engine run hours, Hobbs meter

- Coolant temperature
- Oil pressure
- Engine speed
- Fuel consumption.

Only one limit value is provided for the engine speed. The maximum speed is 1600 RPM. It is assumed that the owner established a schedule that calls for generator checks every Wednesday morning from 8:00 AM to 9:00 AM local time during which the generator is not available. The example below shows an instance of the SPVSGEN data object for normal operation of the generator.

Component Name	**Values Based on Example**	**Comments**
SPVSGEN		Supervisory control
|__ID	ASHRAE123	Identifies generator site
| Numgen	1	1 generator to be controlled
|__KWAvail |	250	Currently available generator capacity on site in kW
|__ThirPtID	Disco123	Utility ID
|__ThirPtNam	Powerdisco	Name of third party
|__Gen[]		Array of length, Numgen=1
|__On |	True	Currently, the generator is on. If On=False generator will be turned off
|__RmRT	200	Remaining hours avail to third party
|__Avail	(see schedule below)	Schedule of availability
|__OpMod	1	Baseload as operational mode
|__Expt	True	Allows export of electricity
|__PrRl | | | | | | | |	{ “G0001/PFRQ”, “G0001/ PUVR”, “G0001/ POVR”, “G0001/ PDPR”, “G0001/ RSYN”, “G0001/ PIOC”, “G0001/ PTOC”, }	Protective relay functions in LogicalDevice G0001 81, 27, 59, 32, 25, 50, 51
|__CumHr |	500	Cumulative hours of runtime under third party control since 1/1 of a year.
|__CumHrTI	123200	Cumulative
|__Mon	(see SYSMON below)	

The schedule for this example is illustrated below:

Component Name	Values Based on Example	Comments
Schd		
|__SchdHdr		
| |__IsEdit	TRUE	Can be remotely edited
| |__NumTEV	1	Has 2 TimEvts
| |__NumRDat	2	Has 2 RDates
| |__Sup | | | | | | | | |	{ {0, b'11111', b'1', b'1', b'11111', b'0', b'0', b'111111'}, {b'100'}, {0x01},}	{ { bits 0..3: no month of year support bits 4..8: supports 24 hours bits 9: support for holiday usage bit 10: support for holiday mode bits 11..15: full day of month support bits 16: no support for one shot events bits 17:no support for range protection bits 18..23: support minute resolution}, { bits 0..2: simple dow support}, {supports event values 0..1}}
|__TimEvts[] |	{8:00A Wed},0 {9:00A Wed},1	Set Evt 0 at 8:00A on Wednesdays Set Evt 1 at 9:00A on Wednesdays
|__RDates[]	{12/25}, {1/1}	Holidays dates Christmas and New Years

The Mon component of the SPVSGEN data model above is shown below at an instant when the generator engine is operating normally:

Component Name	Values Based on Example	Comments
SYSMON		
|__Name	Diesel 1	Name of generator
|__NumMx	5	Number of system parameters monitored
|__Comp[0]		Hobbs meter
| |__i	2000	2000 hours on Hobbs meter
|__Comp[1]		Coolant temperature
| |__i	80	Value of coolant temperature in [C]
|__Comp[2]		Oil pressure
| |__i	3.5	Value of oil pressure [bar]
|__Comp[3]		Engine speed in [RPM]
| |__i	1500	Value of engine speed
| |__hl	1600	Upper limit for RPM
|__Comp[4]		Fuel consumption
|__i	1	Value of fuel consumption in [kg/min]

The protective relaying data model for the example is extensive and covers many pages. Manufacturers of switchgear and protective relay equipment have developed data models with a great degree of specificity regarding each relay functions. It should be noted that modern protective relay switches are complex microprocessor-based systems with fast analog-to-digital converters that sample and process electric properties at very high frequency to identify power quality events. For reasons of clarity, the above example of the relay model is omitted.

6.9 Weather Services Model

The weather services model presented herein is primarily based on the METAR standard for weather reporting provided through the National Oceanic and Atmospheric Administration, NOAA [FMH1, 1998]. In addition, the ASHRAE WYEC2 definitions were incorporated into the model [Stoffel, et al., 1998].

The weather models start with the WEA model, which represents a hypothetical weather station. This weather station can generate two standardized reports – WEARPT and WEAFCST.

The first provides a weather report, WEARPT, which contains current weather information. The second provides a weather forecast, WEAFCST, and contains periodic weather data profiles.

6.9.1 WEA Model

The WEA model describes a complete weather data monitoring device. It contains a complete set of measurements of interest. Any given weather station might have but a small subset of the defined measurements.

For example, a commercial building might have an outdoor temperature and humidity sensor and a measure of solar incidence. This set can be viewed as a small weather station for the purposes of reporting micro-climate data.

<table>
<tr><th>Component Name</th><th>CLASS</th><th>FC</th><th>Description</th></tr>
<tr><td>WEA</td><td>STRUCT</td><td></td><td>Weather</td></tr>
<tr><td>| |__Src</td><td>VSTR20</td><td>DC</td><td>Source of information</td></tr>
<tr><td>| |__t</td><td>t</td><td>MX</td><td>Timestamp of report</td></tr>
<tr><td>| |__loc</td><td>loc</td><td>DC</td><td>Location</td></tr>
<tr><td>| |__Rad</td><td>STRUCT</td><td></td><td>Solar radiance</td></tr>
<tr><td>| | |__Horiz</td><td>AI</td><td></td><td>Horizontal</td></tr>
<tr><td>| | |__Dir</td><td>AI</td><td></td><td>Direct</td></tr>
<tr><td>| | |__XtraTer</td><td>AI</td><td></td><td>Extraterrestrial</td></tr>
<tr><td>| | |__Diff</td><td>AI</td><td></td><td>Diffuse</td></tr>
<tr><td>| |__Illum</td><td>STRUCT</td><td></td><td>Solar illuminance</td></tr>
<tr><td>| | |__Horiz</td><td>AI</td><td></td><td>Horizontal</td></tr>
<tr><td>| | |__Dir</td><td>AI</td><td></td><td>Direct</td></tr>
<tr><td>| | |__Diff</td><td>AI</td><td></td><td>Diffuse</td></tr>
<tr><td>| | |__Zen</td><td>AI</td><td></td><td>Zenith</td></tr>
<tr><td>| |__Sky</td><td>STRUCT</td><td></td><td></td></tr>
<tr><td>| | |__Status</td><td>ENUM8</td><td></td><td>Sky conditions</td></tr>
<tr><td>| | |__Vis</td><td>AI</td><td></td><td>Visibility</td></tr>
<tr><td>| | |__Cvr</td><td>AI</td><td></td><td>Cloud cover</td></tr>
<tr><td>| | |__OpqCvr</td><td>AI</td><td></td><td>Opaque sky cover</td></tr>
<tr><td>| | |__Snow</td><td>AI</td><td></td><td>Snow cover</td></tr>
<tr><td>| |__ComDWC
| | |</td><td>STRUCT</td><td></td><td>Common Descriptor of weather conditions</td></tr>
<tr><td>| | |__Status</td><td>ENUM8</td><td></td><td>Overall status</td></tr>
<tr><td>| | |__DryTmp</td><td>AI</td><td></td><td>Dry-bulb temperature</td></tr>
<tr><td>| | |__WetTmp</td><td>AI</td><td></td><td>Wet-bulb temperature</td></tr>
<tr><td>| | |__Bar</td><td>AI</td><td></td><td>Barometer</td></tr>
<tr><td>| | |__Hum</td><td>AI</td><td></td><td>Humidity</td></tr>
<tr><td>| | |__DegCool</td><td>INT16U</td><td></td><td>Cooling degree days</td></tr>
<tr><td>| | |__DegHeat</td><td>INT16U</td><td></td><td>Heating degree days</td></tr>
</table>

Component Name	CLASS	FC	Description
| | |__HiTmp	AI		Maximum temperature
| | |__LowTmp	AI		Minimum temperature
| |__Wind	STRUCT		Wind conditions
| | |__Dir	INT16U		Direction
| | |__Spd	AI		Average speed
| | |__Gst	AI		Gust speed
| |__Precp	STRUCT		Preciptitation
| |__Typ	ENUM8		Type of precipitation
| |__Prob	INT8U		Probability of precipitation
| |__Tot	AI		Total amount for occurrence
| |__Rat	AI		Current rate of precipitation
|__Rpt	DS	DS	Weather report data set
|__RptGen	RPT	RP	Report description
|__Fcst	WEAFCST		Weather forecast

Src
Weather Bureau Army Navy (WBAN) identification number or ICAO station identifier coded as a visible string. WBAN numbers are five digits. ICAO identifiers are four characters. Alternately an visible string version of an object identifier could be used to identify a private station.

t
Timestamp of the report.

loc
location of weather station. This could be an ICAO or WBAN weather station of a small station for a campus of one building.

Rad
Solar radiance.

Horiz
Horizontal solar radiance.

Dir
Direct solar radiance.

XtraTer
Extraterrestrial solar radiance.

Diff
Diffuse solar radiance.

Illum
Solar illuminance.

Horiz
Horizontal solar illuminance.

Dir
Direct solar illuminance.

Diff
Diffuse solar illuminance.

Zen
Zenith of solar illuminance.

Sky
Description on sky condition.

Status
Sky condition.

Vis
Visibility in horizontal line on ground

Cvr
Cloud cover in percent or fraction of entire sky.

OpgCvr
Opaque cloud cover.

Snow
Snow cloud cover.

ComDWC
Common descriptor of weather conditions. This includes weather data commonly used in weather reporting. It is a subset of the entire weather description.

Status

[1]	measured data
[2]	data derived from weather model

DryTmp
Dry-bulb temperature.

WetTmp
Wet-bulb temperature.

Bar
Barometric pressure.

Hum
Relative Humidity

DegCool
Cooling degree days for current month. DegCool is a cumulative measure derived by the following relation: DegCool=(Ta-T) N/24, where N is the number of hours for which the average temperature Ta is computed and T is the reference temperature. T=18 C. DegCool>= 0. The hours N start from midnight of the first day of the month.

DegHeat
Heating degree days for current month. DegHeat is a cumulative measure derived by the following relation: DegCool=(T-Ta) N/24, where N is the number of hours for which the average temperature Ta is computed and T is the reference temperature. T=18 C. DegHeat>= 0. The hours N start from midnight of the first day of the month.

HiTmp
Daily maximum dry-bulb temperature.

LowTmp
Daily minimum dry-bulb temperature.

Wind
Descriptor for wind conditions

Dir
The true direction (based on geographic north) from which the wind is moving at a given location.

Spd
The rate at which air is moving horizontally past a given point. Averaged as a 2-minute average speed.

Gst
Rapid fluctuations in wind speed with a variation of 10 knots or more between peaks and lulls. Gust is expressed as instantaneous wind speeds.

Presp
Precipitation condition. It includes liquid and solid form of water.

Typ

[1]	drizzle
[2]	hail
[3]	ice pellets
[4]	rain
[5]	snow
[6]	unknown precipitation. Precipitation type that is reported if the automated station detects the occurrence of light precipitation but the precipitation discriminator cannot recognize the type.

Prob
Probability of precipitation.

Tot
Total cumulative amount of daily precipitation.

Rat
The amount of water, liquid or solid, that reaches the ground in a specified period of time.

Rpt
Weather report data set.

RptGen
Description of weather report

Fcst
Structure that contains time series of a weather report.

6.9.2 WEAFCST Model

A weather forecast is a class derived from the Prof class that represents time series of measurements. In this case, the time series may include both historical data and predictions.

Component Name	CLASS	FC	Description
WEAFCST	Prof		Weather forecast

6.9.3 WEARPT

The weather report itself is a DataSet of the weather model WEA. The DataSet is a list of references to components of the WEA data object. By specifying only those individual components of the data object for which data exist, we can omit the transport of the entire data object.
Note that there are many components of which few are mandatory. Also note that most measurements are returned as integers with optional floating point scales at the end of the report. This would permit the transport of the scales less frequently and only the integers containing the precision at other times.

DataSet: WEA.RPT

WEA.DC.Src
WEA.MX.t
WEA.DC.loc
WEA.MX.Rad.Horiz.i
WEA.MX.Rad.Dir.i
WEA.MX.Rad.XtraTer.i
WEA.MX.Rad.Diff.i
WEA.MX.Illum.Horiz.i
WEA.MX.Illum.Dir.i
WEA.MX.Illum.Diff.i
WEA.MX.Illum.Zen.i
WEA.MX.Sky.Status
WEA.MX.Sky.Vis.i
WEA.MX.Sky.Cvr.i
WEA.MX.Sky.OpqCvr.i
WEA.MX.Sky.Snow.i
WEA.MX.Wea.Status
WEA.MX.Wea.DryTmp.i
WEA.MX.Wea.WetTmp.i
WEA.MX.Wea.Bar.i
WEA.MX.Wea.Hum.i
WEA.MX.Wea.DegCool
WEA.MX.Wea.DegHeat
WEA.MX.Wea.HiTmp.i
WEA.MX.Wea.LowTmp.i
WEA.MX.Wind.Dir
WEA.MX.Wind.Spd.i
WEA.MX.Wind.Gst.i
WEA.MX.Precp.Typ
WEA.MX.Precp.Prob
WEA.MX.Precp.Tot.i
WEA.MX.Precp.Rat.i
WEA.MX.Rad.Horiz.s
WEA.MX.Rad.Dir.s
WEA.MX.Rad.XtraTer.s
WEA.MX.Rad.Diff.s
WEA.MX.Illum.Horiz.s
WEA.MX.Illum.Dir.s
WEA.MX.Illum.Diff.s
WEA.MX.Illum.Zen.s
WEA.MX.Sky.Vis.s
WEA.MX.Sky.Cvr.s
WEA.MX.Sky.OpqCvr.s
WEA.MX.Sky.Snow.s
WEA.MX.Wea.DryTmp.s
WEA.MX.Wea.WetTmp.s
WEA.MX.Wea.Bar.s
WEA.MX.Wea.Hum.s
WEA.MX.Wea.HiTmp.s
WEA.MX.Wea.LowTmp.s
WEA.MX.Wind.Dir.s
WEA.MX.Wind.Spd.s
WEA.MX.Wind.Gst.s
WEA.MX.Precp.Tot.s
WEA.MX.Precp.Rat.s

6.9.4 Example of Weather Report WEA.RPT

The example of the weather report is based on weather observation by the University of Washington, Department of Atmospheric Science for January 14, 1999, 12:00 PM Pacific Standard Time.

Table 6-6: Sample of a Weather Observation from University of Washington, Seattle

Time (UTC)	Pressure [mbar]	Dry bulb Temp [F]	Wind direction	Wind speed [knots]	Wind gust [knots]	Rain [0.01”]	Radiation [W/m^2]
20:00:48	**1009.5**	**52**	**193**	**13**	**24**	**0**	**41.23**

Note: UTC : Universal Coordinated Time formerly, Greenwich Mean Time

The WEA.RPT model can be expressed as shown below

DataSet: WEA.RPT	**Values Based on Example**	**Description**
WEA.DC.Src	University of Washington	University of Washington
WEA.MX.t	20:00:48 (UTC)	20:00:48 (UTC) or 12:00 pm PST
WEA.DC.loc	Roof, Dept. of Atm. Science	O
WEA.MX.Rad.Diff.i	41.23	O
WEA.MX.Wind.Dir	193	O
WEA.MX.Wind.Spd.i	13	O
WEA.MX.Wind.Gst.i	24	O
WEA.MX.Precp.Typ	1	[2]: RA Rain
WEA.MX.Wea.Bar.s	1009.5	Mbar
WEA.MX.Precp.Rat.i	0	Inch per hour

6.10 Energy Efficiency Models

Because no prior standardization work has been performed in defining data model that express energy efficiency parameters, two new and basic data models are proposed.

ConsEvt is a model that describes generically a consumption event. The ENEFF data model defines timeseries of energy indices. The timeseries can consist of one index (scalar) or many. In the most typical case, hourly load profiles for baselining purposes are transmitted as a timeseries. The most aggregated form of consumption data can be expressed as an energy consumption over 1 year. All typically used time intervals can be envisioned as well (e.g., over one week, month, season). The DataObject model also contains sufficient information to generate normalized energy efficiency parameter such kWh/m^2 or kWh/occupant. Floor area data or scheduling information for occupancy must be known.

6.10.1 ConsEvt Model

The following model describes a generic description of a consumption event. A consumption event is some sequence of consumption of a utility that can be potentially used in a disaggregated bill for consumption. Some examples of a consumption event include:

- Energy consumption over a period of time by a specific piece of equipment
- Use by a tenant of a utility over some period of time
- Refueling of an electric vehicle by a customer or a guest
- Consumption by a subsystem or manufacturing process
- By a specific person or persons

The structure of the proposed ConsEvt model is shown below.

Component Name	CLASS	FC	Description
ConsEvt	STRUCT		Consumption event
|__d	d	DC	Description
|__Typ	ENUM8	DC	Type of accumulation described
|__NormId	VSTR32	AS	Normalization identification
|__TotCons	FLT32	MX	Total consumption of Prof
|__NormMx	FLT 32	ST	Value of normalization measure
|__NormPred	FLT 32	ST	Predicted value
|__Prof	Prof	LG	Time series of consumption

ConsEvt

Consumption event represents the consumption of a utility in conjuntion with either time, persons, geographical, or functional usage.

d

Description of consumption event.

Typ

Type of normalization of accumulated of consumption described:

[1]	Not defined
[2]	By personell
[3]	By equipment
[4]	By subsystem
[5]	By geographic reference – zone, floor, etc..

NormID
Normalization ID to express normalized energy indices (e.g., floor area or occupants). This can contain a visual string version of an object identifier or a simple name identifier. If consumption event is associated with a customer account, for example, this ID would be an account identifier. If it were a geographic reference, it might be a string describing it such as "Conference Center."

TotCons
Total consumption described in Prof.

NormMx
Normalization measurement value – e.g., number of persons, surface area, number of zones.

NormPred
Predicted normalization value.

Prof
Time series of measurements under this consumption event. Components of Prof describe the actual measurement being made and therefore must be included. Therefore it must include the following optional components of profile:

Prof.Chan[].Nam or Prof.Chan[].AI

6.10.2 ENEFF Model

The ENEFF model describes the completely disaggregated components of consumption related to a utility.

Component Name	CLASS	FC	Description
ENEFF	STRUCT		Contains efficiency summary
|__ID	VSTR32	DC	Identifies Customer
| __NumMx	INT16U	DC	Number of sub-metered circuits
|__Cmps[]	ConsEvt []		Component of sub-metered.
|__typ	ENUM8	ST	type of the index
|__EffIdx	FLT32	ST	Energy efficiency index

ENEFF
Energy Efficiency DataObject model. For example, (1) total facility, (2) cooling plant, (3) heating plant; (4) ventilation, (5) lighting, etc.

ID
Identification of building for which EE DataModel applies

NumMx
Number of metered systems/circuits, such as: total facility, cooling plant, heating plant, lighting, and any other metered process. It is the dimension of the Comps array.

Comps[]
An array of components of the ENEFF. Each element is an individual consumption event, ConsEvt, that contributes to the total aggregated consumption. For instance: (1) total facility, (2) cooling plant, (3) heating plant; (4) ventilation, (5) lighting, etc.

typ
Type of the index

EffIdx
The energy index itself.

6.10.3 Example of the ENEFF Model

Assume a service provider requests an aggregated electric energy (kWh) usage for the total facility normalized by floor area of each facility (i.e. kWh/m^2/month) for the month of August 1998. Assume further that facility "AAA" consumed 720 MWh over one month period and has a total floor area of 30,000 m^2 (300,000 ft ^{2}). The reply from facility “AAA” is shown below.

Component Name	Values Based on Example	Description
ENEFF		Contains efficiency summary
|__ID	AAA	Facility AAA
| __NumMx	1	Number circuits metered = 1
|__Cmps[0]		
|__Typ | |	5	Normalized by geogr. reference Applied to this example, it is the “floor”
|__EffIdx	24	720,000/30,000=24

The consumption event data object model may not need to be transmitted because the index ‘kWh/m^2/month’ was requested. The underlying consumption events for the index are shown below.

Component Name	Values Based on Example	Description
ConsEvt		Consumption event
|__d	total facility KWh	
|__Typ	5	Normalization by floor area
|__NormId |	kWh/m^2	Normalization identification expressing kWh/m^2
|__TotCons	720,000.0	
|__NormMx	30,000	Value of floor area
|__NormPred		Predicted value
|__Prof	Prof	Time series of consumption

The ‘Prof’ data object expresses the full description of a time series of consumption events as shown below. The summation of all individual consumption measurements of event equals 720 MWh. Listed below are consumption events for each hour. Therefore, the time interval in milliseconds is 3,600,000.

Component Name	Values Based on Example	**Description**
Prof		Profile
|__t	{0x0295ed34, 0x15d5}	3/22/1999, 12:03:00.02 PM
|__NumChan	1	Number of channels
|__NumIntv	744	Number of intervals (24 x 31 = 744)
|__Intvl	{0x02255100,0}	One hour per interval
|__Chan[0]		Channel descriptors
| |__AI		Measurement complete description
| | |_r	99999	Corresponding to 99.999KWH
| | |_t	{0x0295ed34, 0x15d5}	3/22/1999, 12:03:00.02 PM
| | |_q	0	Value is valid
| | |_u	72	Wh
| | |_s	0.001	1 Wh per count
| | |_o	0.0	No offset (trimmed out in hardware)
| |__Nam	“E0001/EMeter.MX.W.r”	Full name of measurement

Component Name	Values Based on Example	**Description**

|__Data[ ][ ]	{
	{0,9999},
	{0,9999},
	{0,9999},
	…
	}
		Interval data sets for channels

6.11 Indoor Air Quality (IAQ) Model

The IAQ model proposed consists of the following three components: (1) primary ambient air quality standards, (2) standards pertaining to indoor environments, and (3) minimum ventilation requirements. The data model is described below:

Component Name	CLASS	FC	Description
IAQ	STRUCT		Contains IAQ data for a building
|__ID	OBJID	DC	Identifies Customer
|__NumZon	INT8U	DC	Number of building zones
|__d	d	DC	Description of Standards used
|__Zones	STRUCT[ ]		Components of air quality per zone
|__IsOut	BOOL	CF	Indoor or outdoor
|__OutDoorIdent	IDENT	AS	Association with what other zone
|__NumSub	INT8U	CF	Number of Substances
|__ChmNam[]	VSTR20[ ]	CF	Chemical names
|__BasUnit[]	u [ ]	ST	Base Unit
|__CurCon[]	FLT32 [ ]	MX	Current concentration
|__VolFlow	FLT32	MX	Volume flow
|__NrmUnt	ENUM6	MX	Normalization unit
|__NrmMx	FLT32	CF	Normalization measurement

IAQ
IAQ data model.

ID
Identification of building for which IAQ data model applies.

NumZon
Number of zones. This includes indoor zones as well as outdoor zones. An outdoor zone is an arbitrary zone that specifies the air that is used for fresh air ventilation.

d
Descriptions of standards used. For instances, OSHA, WHO, NIOSH (REL), ACGIH (TRL), MAK.

Zones[]
Array of components of the IAQ. Elements represent IAQ parameters for one zone.

IsOut
Boolean flag. Set True if zone is an outdoor air zone. Set False if zone is indoor air zone.

OutDoorIdent
References an indoor zone to its associated outdoor air zone. The outdoor zone provides fresh air to the indoor zone.

NumSub
Number of substances to be monitored.

ChmNam[]
Array of chemical substances.

BasUnits[]
Array of units for the substances. The units are enumerated in the CASM class “u” found in the appendix to this document.

CurCon[]
Array of concentrations of substances.

VolFlow
Measurement of volume flow.

NrmUnt
Normalization unit defines the basis of aggregation of information:

[1] undefined
[2] person
[3] area
[4] volume

NrmMx
Normalization measurement. A measurement of the NrmUnt that is the basis.

6.11.1 Example of IAQ Model

Assume a small, commercial office building has the following characteristics:

- VAV ventilation system with one AHU and one economizer
- 2 zones with estimated 40 occupants per zone
- each zone has a CO_2 and mixed-gas (oxidizable gases) probe.
- The air quality and airflow in the outdoor air intake is measured. Air-quality is measured with a mixed-gas sensor

The IAQ model could then be expressed as follows:

Component Name	**Values based on Example**	**Comments**
IAQ		Contains IAQ for a building
|__ID	2.6.840.12345	Identifies Customer
|__NumZon |	3	Number of zones. 2 indoor + 1 outdoor zone
|__d | |	“ASHRAE 62, 1989 and NIOSH (REL)”	ASHRAE 62, 1989 and NIOSH (REL)
|__Zones[0]		Zone 1: Indoor zone 1
| |__OutID	False	False: indoor zone
| |__OutDoorIdent	“IAQ.Zone[3]”	Ref. outdoor-air zone 3
| |__NumSub	2	2 substances
| |__BasUnit	{1,1}	Represents ppm
| |__ChemNam	{CO_2, MixGas}	CO_2 and MixGas
| |__CurCon	{650, 600}	(Arbitrary concentrations)
| |__VolFlow	900	Volume flow M^3/s
| |__NrmUnt	2	Persons
| |__NrmMx	40.0	40 people

Component Name	**Values based on Example**	**Comments**
|__Zones [1]		Zone 2: Indoor zone 2
| |__OutID	False	False: indoor zone
| |__OutDoorIdent	"IAQ.Zone[5]"	Ref. outdoor-air zone 5
| |__NumSub	2	2 substances
| |__BasUnit	{1,1}	Represents ppm
| |__ChemNam	{CO_2, MixGas}	CO_2 and MixGas
| |__CurCon	{650, 600}	(Arbitrary concentrations)
| |__VolFlow	900	Volume flow M^3/s
| |__NrmUnt	2	Persons
| |__NrmMx	27	27 people
|__Zones[2]		Zone 3: Outdoor zone 1
|__OutID	True	True : outside zone
|__NumSub	2	2 substances
|__BasUnit	{1,1}	Represents ppm
|__ChemNam	{CO_2, MixGas}	CO_2 and MixGas
|__CurCon	{350, 300}	(Arbitrary concentrations)
|__VolFlow	1800	Volume flow

6.12 Dynamic Demand Bidding

The dynamic bidding model is loosely based on the California Power Exchange bidding protocol and the "Auction API" [PBEP, 1997], [O'Malley and Kelley, 1998]. The following transactions must be supported in a dynamic bidding model:

- Submit a bid: Submit a bid to consume or supply a commodity.
- Withdraw a bid: Withdraw a previously submitted bid.
- Determine bid status: Determine status of a bid.
- Acceptance notification: Receive notification of a bid acceptance.
- Announce last clearing price: Receive notification of last clearing pricing information.

Some other services that an actual bidding system might need to support include:

- Confirmation Acknowledgement of contract award acceptance
- Financial transactions Support of the bidding relationship such as deposits, escrow, etc.

The implementation of the dynamic bidding model is accomplished with three modeling components:

UBID — A utility-based bid describing a transaction involving the supply or demand of a commodity.

MARKET — A market for the commodity.

BIDDER — A bidder that participates in the market by either acting as a supplier or consumer.

6.12.1 UBID component

The UBID component describes the necessary and optional components necessary to describe a bid to supply or consume a commodity. It is also used in the announcing of an award. The UBID model is defined below.

Component Name	CLASS	FC	Description
UBID	STRUCT	SP	Bid for commodity
|__BidSrc	OBJID		Source of bid
|__RefID	INT32		Reference id of this bid
|__BidType	BSTR16		Bid type
|__Cmdty	ENUM16		Commodity to trade
|__ComDWC |	ComDWC		Common descriptor of weather conditions
|__u	u		Units for qty numbers
|__SvcPtID	OBJID		Point of service
|__AsstID	OBJID		Asset ID
|__Schdlng	ENUM8		Scheduling type
|__SttTim	BTIME6		Start time of schedule
|__Intvl	BTIME6		Interval between curves
|__NumScds	INT16U		Number of schedules
|__Schd	Schd		Scheduling of pricing
|__NumCrvs	INT16U		Number of price curves
|__PxCrvs	STRUCT [ ]		Pricing curves
|__MaxPx	FLT32		Maximum price
|__MaxQty	FLT32		Maximum quantity
|__MinPx	FLT32		Minimum price
|__MinQty	FLT32		Minimum quantity
|__NumPxQty	INT16U		Number of Price/Qty
|__PxQty	STRUCT [ ]		Price/Qty curve
|__Px	FLT32		Price element
|__Qty	FLT32		Quantity element

<u>UBID</u>
An offer bid to provide a commodity.

<u>BidSrc</u>
The object ID representing the bidder. This unique ID represents the globally unique identity of the bidder.

<u>RefID</u>
A reference used to identify this bid. The RefID must be globally unique within the scope of the BidSrc. Therefore, the bidder can uniquely identify all of its outstanding bids.

<u>BidType</u>
A classification of the bid relative to the nature of the bidder. The individual bits in the bit string represent the set of tagged characteristics of the bidder.

[1]	Supply (TRUE), Demand (FALSE)
[2]	Aggregated (TRUE), Disaggregated (FALSE)
[3]	Customer owned (TRUE)
[4]	System resource (TRUE)
[5]	Award notification (TRUE)
[6]	Original bid (TRUE)
[7]	Adjustment bid (TRUE)
[8]	Supplemental bid (TRUE)
[9]	Increment bid (TRUE)
[10]	Decrement bid (TRUE)

Cmdty
Commodity to be traded.

[1] Electric power, (default units W)
[2] Natural gas, (default units m^3)
[3] Water, (default units m^3)
[4] Fuel oil, (default units m^3)

Cur
Currency ID (see Cur in section on Tariff model (Tariff.Cur).

u
This represents the units of measure of commodity. Note that for electricity it is likely Watts. For other fuels, the price basis might be energy equivalent, volume, or gross weight.

SvcPtID
An identifier of the point of service usage (if demand bid) or service entry (if supply bid).

AsstID
An identifier of the asset that is the source or destination of the commodity.

Schdlng
The model supports two types of scheduling: (1) interval-based that is has a starting period and an interval between periods, and, (2) an arbitrary schedule.

Scheduling type:

[1] Interval, i.e. 24 hour schedules
[2] General, TimEvt based arbitrary schedule description

SttTim
Starting time of interval-based schedule of pricing. This is only present if this is the “interval” type of schedule.

Intvl
Interval of time for scheduling type [1]. This is only present if this is an interval type of schedule.

NumScds
Number of scheduled price curve transitions included. This is only present if this type of schedule is a general schedule.

Schd
Schedule of pricing curves to present. This is only present if this is general schedule type of schedule.

NumCrvs
Number of pricing curves present corresponding to the scheduled transitions in Schd.

PxCrvs
PXCrvs contains an array of price vs. quantity pairs that together define a curve that can be used in determining supply and demand price elasticity. Each curve defines limits.

MaxPx
Maximum price to be paid for commodity.

MaxQty
Maximum quantity of the commodity offered or consumed.

MinPx
Minimum price to be paid for a commodity.

MinQty
Minimum quantity of the commodity offered or consumed.

NumPxQty
Number of price vs. quantity pairs.

PxQty
Array of price vs. quantity pairs that represents monotonically increasing price.

Px
Price element of price vs. quantity pair.

Qty
Quantity element of price vs. quantity pair.

6.12.2 BIDDER Model

The BIDDER model is contained in any participant in a market for a given commodity. A separate BIDDER instance might exist for each separate commodity contended for by a given market participant.

Component Name	CLASS	FC	Description
BIDDER	STRUCT	ST	Bidder
|__StatBID	STRUCT	ST	Status of bid
| |__BidSrc	OBJID		Source of bid
| |__RefID	INT32		Reference id of this bid
| |__Status	BSTR16		Status of bid
|__Aggr	UBID	SP	Aggregated bid
|__Assets	UBID [ ]	SP	Asset based bids
|__Award	UBID	CO	Award based on bid

StatBID
Status of a bid. A client of the MARKET can write to this member to inform the MARKET of the request for a status update. The MARKET would accept the request and ultimately write the StatBID component of the corresponding BIDDER.

BidSrc
The object ID representing the bidder. This unique ID represents the globally unique identity of the bidder.

RefID
A reference used to identify this bid. The RefID must be globally unique within the scope of the BidSrc. Therefore, the bidder can uniquely identify all of its outstanding bids.

Status
The status of a bid:

[1] Accepted
[2] Rejected
[3] Pending

Aggr
Aggregated bid. The is a default bid for supplemental bids used for bill settlement under real-time load conditions

Assets
Array of default bids for each generator or load

Award
Award by PX expressed in price vs. quantity pairs.

6.12.3 Market Model

A central repository model is proposed that keeps track of bidding and market clearance information during each step of the entire bidding process. The entity that conducts the commodity market needs to expose the part of the model to its clients for market clearing information notification. Bid information about other bidders and their respective bids are expected to be sheltered. The proposed MARKET model is presented below.

Component Name	CLASS	FC	Description
MARKET	STRUCT	ST	Market for commodity
|__Mmbrs	OBJID [ ]	AS	Members of MARKET
|__MakBid	UBID	CO	MakeBid command
|__ChkBid	STRUCT	CO	ChkBid command
| |__BidSrc	OBJID		Source of bid
| |__RefID	INT32S		Reference id of this bid
|__CnclBid	STRUCT	CO	ChkBid command
| |__BidSrc	OBJID		Source of bid
| |__RefID	INT32S		Reference id of this bid
|__Iter	INT8S	ST	Iteration of bid process
|__LCP	UBID	ST	Last clearing price

<u>ChkBID</u>
Command to check and verify bid based on the entity and reference ID which uniquely define a bid.

<u>BidSrc</u>
The object ID representing the bidder. This unique ID represents the globally unique identity of the bidder.

<u>RefID</u>
A reference used to identify this bid. The RefID must be globally unique within the scope of the BidSrc. Therefore, the bidder can uniquely identify all of its outstanding bids.

<u>CnclBID</u>
Command to cancel bid based on the entity and reference ID which uniquely define a bid.

<u>Iter</u>
Iteration of the bid process, for multiple bid scenarios. During active bidding, the Iter increments from 1..n during the rounds of the bid process. The value of –1 is reserved to indicate the bidding is closed.

<u>LCP</u>
Last clearing price. This status member is exposed to all interested parties to determine the "last clearing price" of the commodity on the previous award.

6.12.4 Example of Bidding and Market Clearing Price Notification

This example is derived from a presentation made to the European Electricity Trading AS[14] It is designed to be an illustration of the California PX operation.

[14] Lysfjord, T. 1998. Draft "Case Study Version 1: Introduction to the New Market", European Electricity Trading AS. Previously available at the California Power Exchange Website. Now available at request to author at : terje.lysfjord@online.no

The referenced paper describes a bidding scenario with four participants, two buyers and two sellers distributed over two zones. There exists a transfer path between the zones with a transmission limit of 500 MW:

For the purpose of this example, Lysfjord's scenario is simplified to a one seller and one buyer bid scenario. It is assumed that no congestion exists in the delivery of power to the buyer. The example presents the demand and supply bids for the Day-Ahead market and the market clearing price notification that each bidding participant will receive after the market is closed and the bids are evaluated. For clarity of the presentation, the example assumes that the bids are constant for all hours of the day. The bids are assumed to be valid from 6:00 AM for a period of 24 hours. The bids are shown in Figure 6-3 below.

Demand (MW)	Price ($/MWH)
500	0
500	20
475	21
475	29
400	30
400	40

Supply (MW)	Price ($/MWH)
0	0
0	17.99
240	18
300	30
600	40

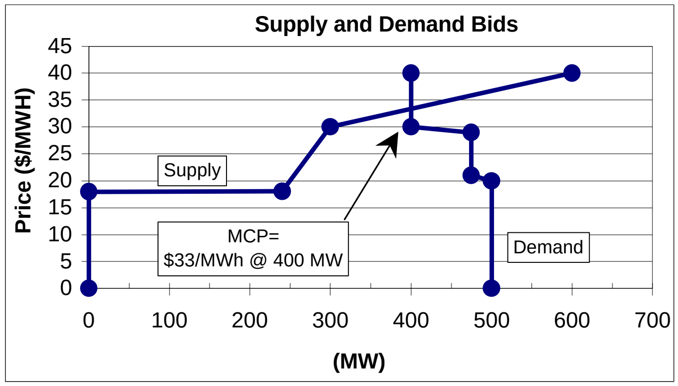

Figure 6-3: Example of a Demand and Supply Bid for Day-Ahead Market

The instances of UBID model are shown below for both the demand and supply bid.
The UBID model for the demand bid can be express as shown below.

Component Name	**Values Based on Example**	**Comments**
UBID		
|__BidSrc	2.16.840.12345	Object ID of bidder organization
|__RefID	234523	Reference ID of this bid
|__BidType	{0,1,1,0,0,1,0,0,0,0,0}	{**demand** bid,customer owned, original}
|__Cmdty	1	Electric power
|__Cur	143	US dollars
|__u	62	W, real power
|__SvcPtID |	2.16.840.2468.1234	Service territory entity 2.16.840.2468, service point 1234
|__Schdlng	1	Interval
|__SttTim	1/15/1999 6:00:00	6:00 AM on 1/15/99
|__Intvl	24:00:00	Day ahead
|__NumScds	1	Single interval – one day
|__NumCrvs	1	
|__PxCrvs[0]		First (and only) price curve
|__MaxPx	40.0	$40.00 / WH
|__MaxQty	5E8	500 MW
|__MinPx	0	0
|__MinQty	4E8	400 MW
|__NumPxQty	6	6 price/quantity pairs
|__PxQty[]	{0,500}, {20,500}, {21,475}, {29,475}, {30,400},{40,400},	

The UBID model for the supply bid can be express as shown below.

Component Name	Values Based on Example	Comments
UBID		
|__BidSrc	2.16.840.4321	Object ID of bidder organization
|__RefID	234523	Reference ID of this bid
|__BidType	{1,1,1,0,0,1,0,0,0,0,0}	{**supply** bid,customer owned, original}
|__Cmdty	1	Electric power
|__Cur	143	US Dollars
|__u	62	W, real power
|__SvcPtID |	2.16.840.2468.1234	Service territory entity 2.16.840.2468, service point 4321
|__Schdlng	1	Interval
|__SttTim	1/15/1999 6:00:00	6:00 AM on 1/15/99
|__Intvl	24:00:00	Day ahead
|__NumScds	1	Single interval – one day
|__NumCrvs	1	
|__PxCrvs[0]		First (and only) price curve
|__MaxPx	40.0	$40.00 / WH
|__MaxQty	6E8	600 MW
|__MinPx	0	0
|__MinQty	2.4E8	240 MW
|__NumPxQty	5	5 price/quantity pairs
|__PxQty[]	{0,0}, {17.99,0}, {18,240}, {30,300}, {40,600}	

The notification of the market clearing price can be communicated via the UBID model. The entity that conducts the market assigns the market clearing to the price-quantity paring in the UBID model and returns the information to the market participants. With a market clearing price of $33 per MWh at 400 MW, the notification messages are listed supply bidder (BidSrc=2.16.840.4321) below. UBID is collapsed to the essential information.

Component Name	Values based on Example	Comments
UBID		
|__BidSrc	2.16.840.4321	Object ID of bidder organization
|__RefID	234523	Reference ID of this bid
|__NumCrvs	1	
|__PxCrvs[0]		First (and only) price curve
|__NumPxQty	1	1 price/quantity pairs
|__PxQty[]	{33,400}	Market clearing price $33 per MWh at 400 MW

7 Overview of Standardization Organizations

Many standards organizations can have a bearing on the communications issues before ASHRAE. These issues include deployment of and inter-networking with BACnet device networks and those of other networks and subsystems. This section summarizes the relevance of the most prominent of those related standards.

Note that the authors present herein a summary of standards as known to them. It is not intended to be an equally exhaustive treatment of all potentially relevant standards.

The standards organizations reviewed generally fall into three categories:

- United States national standards organizations
- International standards organizations
- Industry consortia and trade groups.

Not to be covered are the myriad proprietary and published private standards.

For each standard discussed, a web URL is presented, followed by the sponsoring bodies own declaration of purpose. Finally, a brief summary of relevance to ASHRAE's BACNet is presented.

7.1 Relevance to ASHRAE

The purpose of the present report is to identify potential services that involve wide area communications with building management systems and other networked devices. Many of the scenarios related in the previous sections involve intercommunication between devices that include those in the domain of BACnet, and, others such as electric meters, distribution automation equipment, and, residential and domestic controls. Therefore, several of the standards efforts reviewed can be considered complementary to BACnet. There is a need for coordination of SSPC 135 with these groups to maximize the potential for interoperability and low cost deployment of scenarios that involve devices using protocols from each group.

Some of the standards reviewed can be considered competitive with BACnet to carry traffic to and from the same devices for which BACnet is intended. For these groups, SSPC 135 might consider liaison to affect the eventual coexistence with the competing standards, and, perhaps to facilitate low cost gateways.

7.2 US National Organizations

7.2.1 American National Standards Institute

http://web.ansi.org/default_js.htm

The American National Standards Institute (ANSI) has served in its capacity as administrator and coordinator of the United States private sector voluntary standardization system for 80 years. Founded in 1918 by five engineering societies and three government agencies, the Institute remains a private, nonprofit membership organization supported by a diverse constituency of private and public sector organizations.

ANSI develops relevant standards itself and authorizes other organizations to develop standards under its auspices for international standardization. Among those organizations that are under the ANSI umbrella are ASHRAE, EIA, & IEEE.

7.2.1.1 ANSI C12 WG 17, Metering Communications

http://www.nertec.com/

This is the working group of ANSI C12, responsible for electric metering standards. WG 17 has the following standards for electric metering communications:

ANSI C12.18	Describes a communications protocol for transporting "Tables" over an optical infrared port.
ANSI C12.19	Defines the structure of data in an electric meter. This standard is identical to standard IEEE 1377.
ANSI C12.21	Dial up modem transport of C12.19 "Tables"
ANSI C12.22	Network transport of C12.19 "Tables." Defines notion of gateways to other protocols.

These standards represent the protocols to be in use for all revenue metering in the United States. Because meter interaction is a fundamental component of energy conservation schemes in commercial buildings, many scenarios presented in this paper require interoperability with electric meters.

7.2.2 ASHRAE SSPC 135 (Standing Standard Project Committee)

http://www.bacnet.org/

This website is dedicated to providing the latest information on BACnet - A Data Communication Protocol for Building Automation and Control Networks. Developed under the auspices of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), BACnet is now an American national standard, a European pre-standard, and a potential global standard. The protocol is supported and maintained by ASHRAE Standing Standard Project Committee 135, whose members have created and provided the content for this website.

Here you will find the latest BACnet news, the status of SSPC 135 activities, a comprehensive bibliography of BACnet publications - some of which are available on-line - along with a wealth of other information. In keeping with ASHRAE's long-standing tradition and policy of non-commercialism, this site contains no advertising. However BACnet's success depends on the implementation of BACnet in commercial products. Thus, we are pleased to offer links to the websites of manufacturers who are supporting BACnet through their product offerings.

The interoperability of other protocols with this group, the authors of BACnet, is the primary focus of this report.

7.2.3 The Institute Of Electrical And Electronics Engineers

http://www.ieee.org/

The Institute of Electrical and Electronics Engineers (IEEE) is the world's largest technical professional society. Founded in 1884 by a handful of practitioners of the new electrical engineering discipline, today's Institute is comprised of more than 320,000 members who conduct and participate in its activities in approximately 150 countries. The men and women of the IEEE are the technical and scientific professionals making the revolutionary engineering advances, which are reshaping our world today.

7.2.3.1 SCC31 Automatic Meter Reading and Energy Management

http://www.amrahq.com/

Promotes the research and development of standards, guidelines, and practices in the field of telemetry technology for meter reading, energy management and customer premises equipment. This field includes automatic meter reading and energy management through telemetry technologies (telephone, radio, power-line carrier, cable, etc.) primarily for gas, electric and water utilities.

The primary output of this group is IEEE 1377, "Utility Industry End Device Data Tables." This document is identical to the ANSI C12.19. Both standards were co-developed and jointly published. There is a small but significant difference between the focus of the IEEE and ANSI committees. That is, SCC31 is interested in all forms of utility metering – gas, water, and electric. The ANSI committee is only concerned with electricity metering.

A second standard, under development, is for telephone-based systems, IEEE 1390, "Utility Telemetry Service Architecture for Switched Telephone Networks."

IEEE P1390.2 "Standard for Automatic Meter Reading via Telephone Network to Telemetry Interface Unit."

IEEE P1390.3 "Standard for Automatic Meter Reading via Telephone - Network to Utility controller."

7.2.3.2 SCC36 Utility Communications

This standards coordinating committee has recently been formulated to be the vehicle for standardization of EPRI's Utility Communications Architecture, UCA. Although just beginning, the work is being forwarded in conjunction with the IEC TC57 WG 10,11, &12 committees.

This is the standards home for "UCA 2." The protocols managed here can be expected to have a large impact on the deployment of intelligent electronic devices in utility distribution and power plant management.

It is also here that the UCA 2 Common Application Services Model will be addressed. The models in this report were developed to be consistent with this generic device modeling specification.

7.2.4 Electronic Industries Alliance, EIA Home Control Systems Committee

http://www.eia.org/

To provide a marketing forum specifically geared to the high-tech industry. CEMA is dedicated to educating and assisting high-tech marketing professionals, offering presentations by top keynote speakers and providing the opportunity to share information, explore common industry issues, problems and solutions.

The EIA produces standard protocols for use in residential consumer electronic applications. However, because there is an extremely fine line between many residential applications and light commercial applications, there is a likelihood that home automation devices will co-exist, if not compete, with building automation devices in the marketplace.

7.3 International Organizations

7.3.1 Data Exchange for Meter Reading, Tariff and Load Control, IEC TC57 WG 9, IEC TC13 WG14

http://www.iec.ch/pinfo1-e.htm

To establish Standards, by reference to ISO/OSI Standards, necessary for data exchanges by different communication media, for automatic meter reading, tariff and load control, and consumer information.

The media can be either distribution line carrier (DLC), telephone (including ISDN), radio or other electrical or optical system, and they may be used for local or remote data exchange.

These IEC committees deal respectively with distribution automation protocols and electronic metering communications. Underlying this work, however, is the DLMS (Distribution Line Messaging Specification) standard, IEC 61334-4-41.

DLMS is a direct competitor of BACnet and the Manufacturing Message Specification, ISO 9506. All three protocols more or less equivalently are optimal protocols for the exchange of SCADA messaging. While DLMS is somewhat less functional than BACnet, it also benefits from this simplicity.

7.3.2 IEC/ISO JTC1 SC25 Working Group 1

http://www.labs.bt.com/profsoc/sc25wg1/ndocs.htm

Working Group 1 is a Working Group of Joint Technical Committee 1 (JTC1), Sub Committee 25. JTC1 is the committee responsible for Information Technology standards under the two international standards bodies: ISO and IEC. The complex relationships between various standards bodies are shown in a map.

This Working Group is producing standards for "Home Electronic System", that is for control communication within homes. This scope includes the control of equipment for heating, lighting, audio/video, telecommunications, security... in fact, any equipment within the home. The group also looks at similar building management functions in commercial buildings. The work is building on proprietary and regional standards activity across the world, and includes active participation from a dozen countries. The work links to other standards bodies dealing with multi-media systems, cabling systems, applications and safety.

The work of this group provides for high level representation of applications in the home and commercial buildings. The group does not provide implementable standards for communications and messaging. However, it does provide valuable insights into the distributed communications applications.

7.3.3 CEN/TC 247 Controls for Mechanical Building Services

http://www.cenorm.be/

“CEN's mission is to promote voluntary technical harmonization in Europe in conjunction with worldwide bodies and its partners in Europe.

Harmonization diminishes trade barriers, promotes safety, allows interoperability of products, systems and services, and promotes common technical understanding.

In Europe, it works in partnership with CENELEC - the European Committee for Electrotechnical Standardization (www.cenelec.be) and ETSI - the European Telecommunications Standards Institute (www.etsi.fr).
Both organizations work on standardization of individual and combination devices and systems for automatic control of mechanical building services installations including devices for heating, ventilating and air-conditioning system controls.

7.3.4 CENELEC TC205

http://www.cenelec.be/

CENELEC together with its members, affiliates and co-operating partners is developing and achieving a coherent set of voluntary electrotechnical standards as a basis to a Single European Market / European Economic Area without internal frontiers for goods and services inside Europe.
For more information on this, see ETSI TC205 below.

7.4 Consortia and Trade Groups

7.4.1 Cebus Industry Council, CIC

http://www.cebus.com/

The CEBus Industry Council is a multi-industry organization of companies, incorporated as a non-profit corporation, to develop and enlarge the market for products compliant with the CEBus Standard and/or the Common Application Language (CAL) as implemented in the Home Plug and Play Specification. The Council maintains the value of its certification marks while facilitating interoperability among products and with multiple transport protocols through the maintenance of the Standard and Specification, its application database, product testing, and conformance certification.
The CIC is responsible for developing an interoperability standard for the use of CEBus Common Application Language, CAL. They are developing a set of detailed models of consumer devices as well as protocols for the use of messaging to share information between devices and subsystems. While CEBus is a peer protocol to BACnet, the CIC goes beyond the "how to say" to "what to say" and "when to say it." This interoperability work is collectively trademarked "Home Plug & Play™."
This is relevant to BACnet because it is typical of the next step required of the committee to achieve interoperability and interchangeability of devices in applications built to the BACnet standard. While there is not widespread deployment of this still-evolving specification, a substantial amount of thought has gone into passive information sharing in a cross-functional environment that has direct applicability to commercial applications.

7.4.2 LonMark Association

http://www.lonmark.org/

The LONMark Association's mission is to enable the easy integration of multi-vendor systems based on LONWorks networks using standard tools and components. Today over 3,500 companies are using LONWorks control networks to provide systems and solutions for building, home, industrial, telecommunications, transportation and other industries. There are over 4 million LONWorks based devices installed worldwide. The Association provides an open forum for member companies to work together on marketing and technical programs to advance the LONMark standard for open interoperable control solutions."

Similar to the CEBus Industry Council, CIC, the LONMark Association is developing an interoperability standard for the use of LONTalk in specific devices. LONMark has gone a long way to define models of well known device functionality such as chillers, thermostats, etc… These models will find there way into most BACnet applications and can therefore help to seed ASHRAE's development of standard device models.

In addition, in many commercial applications, BACnet can be applied as a mezzanine bus for sub-system controllers, using LONTalk as a lower level sensor bus.

7.4.3 European Installation Bus Association, EIBA

http://www.eiba.com/

EIBA, the European Installation Bus Association, is an organization with a worldwide scope. Our name reflects our initially European roots. Within EIBA, over 85 leading electrical installation companies have joined forces, in a unique blend of cooperation and competition.

Our objectives:

- Furthering the development of a unified concept for electrical fitting and home and building management.
- Establish the EIB logo and trademark as a guarantee for quality and interworking of EIB products and solutions. Our way of operation:
- Make the EIB system know-how available to members and licensees.
- Provide members and licensees with support and documentation.
- Ensure the coordination of EIB-related activities.
- Further the EIB standard through our member companies by an active presence on the market, in national and international bodies and projects.
- Establish and supervise appropriate criteria for quality and compatibility, with the help of external test institutes.
- Support adequate training for EIB developers and electrical fitters.
- Maintain the position of the EIB Tool Environment (ETE) as an unrivaled platform for open software tool development - at the heart of which ETS (the EIB Tool Software) offers a common tool for the configuration of EIB installations. "

The EIBA has developed a standard protocol for buildings and home automation networks. They are also leading an effort termed "The Convergence Project" that seeks to

merge EIB with Batibus and HES. Essentially a peer standard to BACnet, this group claims to have a large installed base of devices and supporting manufacturers.
EIBA is a competitive protocol to BACnet in that it supports the reading and writing of SCADA objects over various networks (primarily power line carrier). The IEBA organization promotes the licensing and adoption of this technology throughout Europe.

7.4.4 International Alliance for Interoperability, IAI

http://iaiweb.lbl.gov/

The IAI is an action oriented, not-for-profit organization. Its mission is to define, publish and promote specifications for Industry Foundation Classes (IFC) as a basis for project information sharing in the building industry (architecture, engineering, construction, and facilities-management. The information sharing is worldwide, throughout the project life cycle, and across all disciplines and technical applications.
IAI concerns itself with the object oriented modeling of all aspects of commercial buildings – from application level communications to representations of building composition, construction, and maintenance.
IAI is developing (as of this writing) models of common components of a building controls system. For this purpose, the work of this group can contribute to the construction of composite BACnet objects to represent unit operations of building controls.

7.4.5 TAP / ETHOS

http://www.ethoseurope.org/

The Telematics Applications Programme (TAP) is part of the European Commissions Framework Programme. TAP has two aims. The first is to promote the competitiveness of European industry and the efficiency of services of public interest and to stimulate job creation through the development of new telematic systems and services. The second is to promote the research activities necessary for other common policies.
The European Telematics Horizontal Observatory Service, ETHOS, identifies and describes the forces driving adoption and deployment of telematic technologies throughout the world, and also provides a brokerage service which will ensure that the resources that TAP projects are made available.
Telematics is derived from the French word 'Telematique' and refers to the use of computers alongside telecommunications systems. As such, telematics ranges from all forms of dial-up service, through the Internet, and onto broadband applications such as Full Service Network.
The work of this organization involves the tracking and sponsoring of projects according to its interests in promoting the involvement of European industry. To this end several of the projects touch on the applications of smart homes and buildings.

7.4.6 European Telecommunications Standards Institute, ETSI TC205

http://www.etsi.fr

The European Telecommunications Standards Institute (ETSI) is a non-profit making organization whose mission is to determine and produce the telecommunications standards that will be used for decades to come. It is an open forum that unites 490 members from 34 countries, representing administrations, network operators, manufacturers, service providers, and users. Any European organization proving an interest in promoting European telecommunications standards has the right to represent that interest in ETSI and thus to directly influence the standards making process."

"To prepare standards for all aspects of home and building electronic systems in relation to the Information Society. In more detail: To prepare standards to ensure integration of a wide spectrum of control applications and the control and management aspects of other applications in and around homes and buildings, including the gateways to different transmission media and public networks taking into account all matters of EMC and electrical and functional safety. TC 205 will not prepare device standards but the necessary performance requirements and necessary hardware and software interfaces. The standards should specify conformity tests. TC 205 will perform the work in close co-operation with relevant CENELEC TCs and those in CEN and ETSI.

8 Recommendations for Initiating Model Standardization

The nature of the information services discussed in this report is highly “inter-domain.” They bridge across the utility meter, just like electric power, to link the separate and autonomous information systems that have evolved independently to either side of the meter and have addressed issues that are specific to either domain. ASHRAE is the first organization to identify and define potential new energy/information services in a generic and systematic way, and, to study the communication requirements necessary for the information exchange between energy service providers and end-users.

In doing so, research is needed to go beyond the boundaries of ASHRAE’s traditional domain of HVAC controls and communication technologies. It additionally involves communication domains for automatic meter reading, distribution automation of electric power systems, and others. It should further encompass data formats and communication procedures developed for weather reporting and for bidding electric power generation and purchases into a power exchange. These various domains have either established protocols and standards in place that define data models for specific services or they are in the process of being established by such standards organization as IEEE, ANSI, and AMRA.

Regardless of which organization is leading standardization efforts for the utility/customer interface, the standard development work for cross-functional standards can be expected to be highly inter-domain and inter-disciplinary. In the absence of collaboration, each group will grow to overlap the others duplicating the modeling and protocol efforts of ASHRAE. The result can be a requirement for a plethora of application gateways in order for the disparate systems to intercommunicate. The additional cost of purchasing, configuring, and commissioning these gateways will be a great obstacle to the deployment of new services, and hence, advanced communications based devices. It is postulated that in the absence of collaboration, many of the otherwise potentially useful services will not materialize in the marketplace because of these costs.

The authors consider that the focus of coordination should be through open United States national standards. The standards framework of BACnet (through ASHRAE), CEBus (through EIA), UCA (through IEEE), and ANSI C12 (through ANSI), can provide for a non-overlapping suite of protocols for interoperable communications. There is currently some non-interoperable overlap. However, a concerted effort at convergence of protocols for utility/customer interfaces could be and will be most likely and most productive approach toward the common goal.

For ASHRAE to be successful in developing cross-functional communication standards, the Society should engage itself in standardization efforts at the following two levels:

1) ASHRAE should use the service definitions and data models proposed in this report as a starting point for developing new BACnet macro objects and services. The appropriate vehicle within the ASHRAE SSPC 135 (BACnet) is the Application Working Group. We presented a mapping approach to map CASM data objects to BACnet data object classes. This mapping approach could be adopted to convert the data objects used in this report to fit the BACnet’s data object definition framework. This work should begin with the proposed StructuredView object presented in the Mapping section. Then, the committee should evolve the data models presented in this report based on the knowledge and experience of its members.

As the ASHRAE SSPC 135 committee, and perhaps other Technical Committees, are reviewing each of the services and data models proposed, it may be appropriate to rank each service according to collective assessment of the timeline at which time the services are likely to be market-ready.

The result of these efforts should be the standardization of data objects and services for the purpose of enabling interoperable building automation system devices to communicate with other service providers.

2) ASHRAE should further develop standardized scenarios for the interoperation of BACnet compliant devices and those of other standards bodies to facilitate their interoperation. This will require close collaboration with other standardization organizations to leverage existing work to the maximum degree possible. Collaboration with other standards organizations is recommended, initially, for the following service domains.

- revenue meter reading models as established by ANSI C12
- On-site generation as established by IEEE SCC21 interconnection of distributed generation
- RTP, direct load control as worked on by the Customer Interface working group of UCA and now further developed under the IEEE auspices of SCC 36.

9 Conclusions

The research focused on the definition of potential and new energy related information services and the proposal of data models that support the services. The report presented a characterization of the current-state-of-the-art of information technology for customer/utility interactions. As part of the characterization of current technology, the literature reviewed and the technologies of various product and services for new and innovative information services were summarized. This literature review was conducted in the spring of 1998 and as such the characterization of technology represents the state-of-the-art until that time.

The findings of the technology characterization revealed that several hundreds of residential customers were participating in pilot studies in which pricing information was communicated to the residential end-user to trigger control actions. A controls manufacturer in collaboration with ERPI developed RTP communication schemes to be seamlessly incorporated into the supervisory HVAC control computer. More recently the technology companies have focussed on web-based applications ranging from direct billing information to remote monitoring and control of HVAC equipment.

Although there was, and continues to be, substantial piloting of potential new services, there was an absence of standardization of the means of expression of the services over data communications networks. Thus, each service could only be implemented through the collaboration with the manufacturers of every device involved in the service.

The principal focus of this research project was centered on the information service definition and the analysis of communication requirement to enable the new services. The following nine information services were defined and their communication and data requirements were analyzed.

1. Revenue meter reading (electricity, gas, water, steam)
2. Quality of service monitoring
3. Real-time pricing transmission
4. Load management services
5. On-site generation supervisory control
6. Energy efficiency monitoring
7. Weather services
8. Indoor-air quality monitoring
9. Dynamic demand bidding into a power exchange.

The result of the service definition and data requirement analysis is a series of proposed data models, which define a set of data and their relation to each other that are necessary for the implementation of a service. The guiding principal for the definition of the data model was to propose a data object framework that enables the implementation of the services that can interoperate across different communication networks and computing platforms. The data object framework consists of data models and procedures to exchange these data. The data models are defined at the highest degree of generality to minimize any constraints on the application of the model, while at the same time maintaining a level of specificity necessary to unambiguously characterize the service functionality.

9.1 Definition of Services

The highlights of the services and the associated data models are summaried below:

- **Revenue meter reading and quality of service monitoring.** Existing work under ANSI C12.19 was utilized to avoid duplicative work. The data models were simplified to extract the main features. They were further modified to fit the data modeling approach of this project. The resulting data models are very detailed and lengthy.
- **Real-time pricing transmission service.** This service provides a framework for transmitting any energy tariff. It can be used for producing energy service bills given the consumption data are available at the appropriate degree of detail. The proposed Tariff model is the result of the attempt to define a versatile data model that can accommodate all of the current electric, gas, water, cooling and heating services tariffs including real-time pricing rates. A detailed example of the Tariff model applied to PG&E's SCHEDULE A-RTP tariff is presented [PG&E SCHEDULE A-RTP, 1998].
- **Energy efficiency monitoring.** Data models for energy efficiency monitoring are defined at a high level of data abstraction. This decision was based on the notion that these services are more likely to be implemented to monitor performance and control at a system level (boiler, chiller, air-handler) rather than at a device component level (e.g., valves, heat exchanger).
- **Load management and on-site generation monitoring**. For load management services, it is the authors' belief that the appropriate level of control capabilities is at the supervisory level, where load targets are being sent to the buildings automation system rather than measures to achieve those targets. Supervisory control of on-site generation is one of several load management options. However, on-site generation interacts with the distribution grid directly, which requires protective relaying functions to isolate the generator from the grid. IEEE has established extensive standards specifying protective relaying functions and operational requirements for generators. With the advent of distributed generation concepts using microturbine and fuel cell generators, issues involving the generator's interconnection to the grid and its controllability by the utility are currently being researched at the IEEE and at interest groups such as the Fuel Cell Council[15].
- **Weather reporting and weather forecasting**. This service utilizes data formats for weather reporting established by NOAA. A micro-climate adjustment service was proposed whereby the subscriber of the service reports to the service provider local building or campus specific weather data. The locational-specific weather information will be used to adjust the regional weather forecast to improve the forecast accuracy.
- **Indoor-air quality monitoring**. The authors recognize the current debate in the IAQ community related to the cause of the sick building syndrome and what reliable parameters ought to be measured and monitored to assure good indoor environmental conditions. In the absence of clear evidence and knowledge in this field, the report proposed a data model that provides a framework that is flexible to support current and future data needs to track indoor-air quality conditions. The data model

[15] Codes and Standards Working Group, Fuel Cell Council, Washington, D.C. See website: http://www.usfcc.com/wg01.htm

accommodates currently agreed upon indoor-air quality descriptors, such as concentrations of surrogate substances (e.g., CO_2). New indoor-air parameters can be added as we gain more insight into this complex issue.

- **Dynamic demand bidding service.** This service automates an electric power procurement mechanism, which currently is available in deregulated electric power market structures, such as in the State of California. This service represents a future scenario of a potential innovative service, which has gained interest in Europe as a means to assist in the overall efficiency improvement of the supply and demand market segments of the electric power system [IEA, 1998a; IEA, 1998b]. Dynamic demand bidding supports the automated bidding process for energy at an energy exchange. This service has been proposed with the electric power procurement in mind, borrowing from procedures and protocols set by the California Power Exchange for the procurement of day-ahead hourly electric power. The demand bidding service proposed is fundamentally applicable to the natural gas spot market as well. The bidding protocols set by the Gas Industry Standards Board in the US is tailored to the natural gas market needs, which differ from those of electric power.

9.2 Data and Service Modeling

- The data modeling was performed using the Common Application Services Model (CASM) developed as part of EPRI's UCA 2 project. CASM provides the unique framework for the representation of devices and device characteristics as viewed over communication networks. Although similar in many respects to BACnet, CASM specifically supports topology-independent message construction, optionality, and transparent customization. CASM supports relatively unconstrained hierarchical modeling that facilitates the logical organization of models. Therefore, CASM was used as the generic object model to represent the data models used in services proposed in this report.
- Translations have been proposed for converting between the common model of services presented in this report and BACnet, LONTalk, and CEBus. For BACnet, this report proposes extensions to the standard to represent hierarchical information, and support topology-independent messaging.

9.3 Recommendations for ASHRAE

Because of the inter-domain nature of the information services discussed in this report, it is not only necessary but unavoidable for ASHRAE to collaborate with other standards organizations, which have created standards in their own domains. The report lists relevant national and international standards organizations and discusses their domains and relevance to the standardization efforts of the services discussed in this project. Two recommendations were proposed for ASHRAE to champion the standardization efforts.

1. ASHRAE should use the service definitions and data models proposed in this report as a starting point for developing new BACnet macro objects and services. The appropriate vehicle within the BACnet SPP 135 is the Object and Services Working Group. This proposed mapping approach could be adopted to convert the data objects used in this report to fit the BACnet's data object definition framework. This work should begin with the proposed StructuredView object presented in the Mapping section. Then, the committee should evolve the data models presented in this report

based on the knowledge and experience of its members. As the BACnet SPP 135 committee, and perhaps other Technical Committees, are reviewing each of the services and data models proposed, it may be appropriate to rank each service according to collective assessment of the timeline at which time the services are likely to be market-ready. The result of this effort should be the standardization of data objects and services for the purpose of enabling interoperable building automation system devices to communicate with other service providers.

2. ASHRAE should further develop standardized scenarios for the interoperation of BACnet compliant devices and those of other standards bodies to facilitate their interoperation. This will require close collaborations with other standardization organizations to leverage existing work to the maximum degree possible. The collaboration with other standards organizations is recommended for the following service domains.

- Revenue meter reading models as established by ANSI C12
- On-site generation as established by IEEE SCC21 interconnection of distributed generation
- RTP, direct load control as worked on by the Customer Interface working group of UCA and now further developed under the IEEE auspices of SCC 36.

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11 Appendix: Detailed ANSI C12.19 meter model

This appendix contains a detailed mapping of the ANSI C12.19 standard meter model. It is based on the preliminary mapping in the reference [EPRI, 1997b], and has been slightly enhanced and extended for this report.

Note that in the description column of the model there are many elements labeled with a direct reference to the ANSI C12.19 standard as follows, showing the table and standard variable name separated by a colon, ":":

`2:E_FREQ`

Components described in this manner are not elaborated on here but can be found in complete detail in the standard.

This section presents the full model in three sections:

1) *Primitives that are enumerations and bitstrings*. These are components that are incorporated into the structures of the full meter model, but are summarized here. Some additional enumerations that are used only once are defined in the description where they are used and not in this section.
2) *Structures*. The structures defined in this section are re-used multiple times in the detailed meter model. To facilitate the readability of the full meter model definition, these structures are defined here and not expanded in detail in the full meter section. When the class column for a component has the name of a structured class, and it is not shown in detail, the details are still assumed to be present.
3) *Full meter model*. This is the final assembly of the C12.19 meter model. All the details are filled in either explicitly or by reference to a previously defined primitive or structured class.

11.1 Primitive Meter Model Components that are Enumerations and Bitstrings

Component Name	CLASS	Description
IEDStat	BSTR16	Electronic device status
LPFlgs	BSTR8	Load profile configuration flags
LPMXQ	BSTR8	Load profile quality flags
LPStFlgs	BSTR8	Load profile set status flags
MtrCnfCls	ENUM8	Meter conformance class
MtrRegFuncs	BSTR16	Register functions
MtrSrcFlgs	BSTR16	Meter Source flags – supported
PkType	ENUM8	Peak type
SRBits	BSTR8	Self read bits
SRSt	SRBITS	status of self read log
TimBas	ENUM8	Time basis of measurement

IEDStat

A bitstring containing flags of significant abnormal conditions in an IED. Definition of I*EDStat* bits:

1	Unprogrammed
2	Configuration error
3	Self check error
4	Ram failure
5	Rom failure
6	Non volatile ram failure
7	Clock error

8	Measurement error
9	Low battery
10	Low input voltage
11	Capacity overload
12	Power failure
13-15	<reserved>

<u>LPFlgs</u>
This bitstring identifies the presence of components of load profile. Description of *LPFlg* bits:

1	Inhibit after overflow
2	Block end read
3	Block end pulse
4	Scalar divisor
5	Extended interval
6	Simple interval
7	<reserved>

<u>LPMXQ</u>
These bits are quality flags describing the validity or consistency of the associated interval value. Description of *LPMXQ* bits:

1	Overflow
2	Partial interval
3	Long interval
4	Power status
5	Test interval
6	Clock set forward
7	Clock set backward

<u>LPStFlgs</u>
Miscellaneous status bits for a meter. Description of *StFlgs* bits:

1	Overflow
2	Inhibit overflow
3	Enabled
4	Test mode
5	Power failure
6	IntervalChanged
7	New install

<u>MtrCnfCls</u>
Describes the conformance block class of meter.

Enumerated values of MtrCnfCls:

1	Simple measurement meter
2-255	<reserved>

<u>MtrRegFuncs</u>
Describes the meter's capability to perform various demand control functions. Bit definitions of *MtrRegFuncs*:

1	season info field flag
2	date time field flag
3	demand reset counter flag
4	demand reset lock flag
5	cumulative demand flag
6	continuous cumulative demand
7	time remaining flag
8	self read inhibit overflow flag
9	self read sequence number flg
10	daily self read flag

11	weekly self read flag
12	self read demand reset
13-15	<reserved>

MtrSrcFlgs

Flags that show support for various algorithms in monitoring demand. Bit definitions of *MeterSrcFlgs*:

1	Power fail aftermath exclusion
2	Reset exclusion
3	Block demand support
4	Sliding demand support
5	Thermal demand support
6-15	<reserved>

PkTyp

Describes the type of peak in a set of peak values associated with a measurement. *PkTyp* enumerations are:

1	maximum reached
2	minimum reached
3	demand reset value

SRBits

Description of *SRBits* bits:

1	Order flag
2	Overflow flag
3	List type flag
4	Inhibit overflow flag
5-7	<reserved>

TimBas

Describes the relevant time basis of a utility measurement. Enumerated values of *TimBas*:

1	bulk quantity
2	Instantaneous
3	period based on fundamental frequency
4	sub-block average
5	block average
6	bulk quantity over interval
7	thermal quantity
8	event accumulation

11.2 Structured Meter Model Components

This section describes several structured meter model components referenced in the next section.

11.2.1 DmdsRcd

Component Name	CLASS	FC	Description [ANSI C12 TABLE:ID]
DmdsRcd	STRUCT	MX	23:DEMANDS_RCRD
|__r	INT40S		23:SUMMATIONS
|__i	INT16S		23:DEMAND
|__CumDmd	INT16S		23:CUM_DEMAND
|__ContCumDmd	INT16S		23:CONT_CUM_DEMAND
|__Pks	Pk [ ]		23:DEMANDS (COINCIDENTS)

DmdsRcd
Contains a description of demand measurements for a single source.

r
Summation value associated with current demand measurement.

i
Current value of demand.

CumDmd
Integral value of demand over time. Value is resetable.

ContCumDmd
Non-resetable integral of demand over time.

Pks
Array of peaks associated with the demands record.

11.2.2 RegDatRcrd

Component Name	CLASS	FC	Description [ANSI C12 TABLE:ID]
RegDatRcrd	STRUCT		23:CURRENT_REGISTER_DATA_TBL
|__Dmds	DmdsRcd [ ]	MX	23:TOT_DATA_BLOCK
|__Tiers	DmdsRcd [ ] [ ]	MX	23:TIER_DATA_BLOCK
|__NumDmdRsts	INT8U	ST	23:NBR_DEMAND_RESETS

RegDatRcrd
Contains the description of current information for a meter's registers.

Dmds
Array of demand records for the measurements of the meter.

Tiers
Contains an array of arrays of records of demand measured on a per-tier basis.

NumDmdRsts
Number of demand resets executed on the meter.

11.2.3 MtrSlfRd

Component Name	CLASS	FC	Description [ANSI C12 TABLE:ID]
MtrSlfRd	STRUCT	LG	
|__Info	UtilSRMXInfo		26:REGISTER_INFO_RCD
|__Data	RegDatRcrd		26:SELF_READ_REGISTER_DATA
|__Seq	INT16U		26:SELF_READ_SEQ_NBR

MtrSlfRd
Meter self read data structure. This is a logged snapshot of the current value of the RegDatRcrd.

Info
See UtilSRMXInfo, below.

Data
Snapshot of meter's register data record.

Seq
Sequence number for tracking sequential self reads.

11.2.4 MtrSRReg

Component Name	CLASS	FC	Description [ANSI C12 TABLE:ID]
MtrSRReg	STRUCT	LG	26:SELF_READ_LIST_RCD
|__SRSt	SRBits		26:LIST_STATUS_BFLD
|__NumEnt	INT8U		26:NBR_VALID_ENTRIES
|__LstEnt	INT8U		26:LAST_ENTRY_ELEMENT
|__LstSeq	INT16U		26:LAST_ENTRY_SEQ_NBR
|__NumUnread	INT8U		26:NBR_UNREAD_ENTRIES
|__SREnt	MtrSlfRd [ ]		26:SELF_READS_ENTRIES

MtrSRReg
A data structure containing an array of MtrSlfRds.

SRSt
Self read status.

NumEnt
Number of valid entries in the table.

LstEnt
Last entry element.

LstSeq
Last sequence number in list.

NumUnread
Number of unread elements.

SREnt
Array of meter self read structures.

11.2.5 UtilSRMXInfo

Component Name	CLASS	FC	Description [ANSI C12 TABLE:ID]
UtilSRMXInfo	STRUCT		26:REGISTER_INFO
|__t	t	MX	26:END_DATE_TIME
|__Season	INT8U	ST	26:SEASON

UtilSRMXInfo
A time stamp of self read information along with a tag for the logical season it occurred in.

t
Timestamp of self read event.

Season
Season id to allow sorting later.

11.2.6 UtilID

Component Name	CLASS	FC	Description [ANSI C12 TABLE:ID]
UtilID	STRUCT	DC	
|__Div	VSTR32		6:UTILITY_DIVISION
|__SvcPt	VSTR32		6:SERVICE_POINT_ID
|__ElecAdr	VSTR32		6:ELEC_ADDR
|__TarifID	VSTR32		6:TARIFF_ID
|__SerNum	VSTR20		6:UTIL_SER_NO

UtilID
Utility specific identification information pertaining to the meter.

Div
Utility division.

SvcPt
Service point at which meter is installed.

ElecAdr
Electric address of the service point.

TarifID
Identification of the tariff used to bill the service being metered.

SerNum
Utility serial number of the meter. Also termed the “logical id” of the meter.

11.2.7 Pk

Component Name	CLASS	FC	Description [ANSI C12 TABLE:ID]
Pk	STRUCT	MX	
|__i	i	MX	23:DEMAND
|__t	t	MX	23:EVENT_TIME
|__PkTyp	PkTyp	MX	22:MIN_OR_MAX_FLAGS
|__Other	i	MX	23:COINCIDENT_VALUES

Pk
This is a description of a single peak measurement. Could be minimum, maximum, …

i
Instantaneous measurement of demand.

t
timestamp of current measurement.

PkTyp
Type of peak measurement.

Other
Coincident value of other measurement for reference.

11.2.8 UtilMX

A measurement class derived from the AI class. UtilMX is extended with information of specific interest in revenue metering. For example, note the addition of a record of recent peak values (Pks).

Component Name	CLASS	FC	Description [ANSI C12 TABLE:ID]
UtilMX:AI	STRUCT		Revenue metering measurement
|__I	i	MX	23:DEMAND
|__f	f	MX	Floating point value
|__t	t	MX	Time stamp
|__q	q	MX	Quality
|__ff	ff	MX	Frozen floating point value
|__fi	fi	MX	Frozen integer
|__ft	ft	MX	Frozen timestamp
|__r	r	MX	23:SUMMATIONS
|__CumDmd	INT16S	MX	23:CUM_DEMAND
|__ContCumDmd	INT16S	MX	23:CONT_CUM_DEMAND
|__Pks	PK [ ]	MX	23:DEMANDS
|__s	s	CF	12:MULTIPLIER
|__o	o	CF	Offset
|__u	u	CF	12:ID_CODE, UCA Enum
|__uco	u	CF	12:ID_CODE UCA Enum
|__min	min	CF	Min value
|__max	max	CF	Max value
|__incr	incr	CF	Increment
|__MxTyp	MxTyp	CF	Measurement type
|__MxRef	MxRef	CF	12:segmentation
|__MxLoc	MxLoc	CF	Measurement location
|__SmpRate	SmpRate	CF	Sample rate
|__NumSmp	NumSmp	CF	Number of samples

Component Name	CLASS	FC	Description [ANSI C12 TABLE:ID]
|__TimBas	TimBas	CF	12:TIME_BASE
|__QuadAcct	BSTR4	CF	12:Q1->Q4_ACCOUNTABLITY
|__NetFlow	BOOLEAN	CF	12:NET_FLOW_ACCOUNTABILITY
|__HarComp	ENUM8	CF	12:HARMONIC
|__NumDms	NumDms	CF	21:NBR_OCCUR
|__pp	pp	CF	Pseudo point
|__db	db	SP	Deadband for change
|__hl	hl	SP	Hi limit
|__ll	ll	SP	Low limit
|__hhl	hhl	SP	High high limit
|__lll	lll	SP	Low low limit
|__d	d	DC	Description of measurement

UtilMX:AI

A measurement class derived from the AI class. UtilMX is extended with information of specific interest in revenue metering. For example, note the addition of a record of recent peak values (Pks).

i

Integer Value, the actual value of the analog point.

f

Floating Point Value, for *Analog Values*, the floating point representation of the *Analog Value* calculated by:

*Floating Point Value = Integer Value * Scale + Offset* (4)

t

Timestamp.

q

Quality, used to indicate if an object value is valid, and if not, the reason for being invalid. Each *Quality* indication is represented as a bit within the Quality component. The bits representing Quality are:

Invalid - Indicates whether or not the associated value is valid or not. If clear (0), the value of this point is valid and can be used in calculations, alarms, etc. If set to (1), the reported value of this point may not be correct and therefore should not be used.

Comm Fail - Indicates communication status. If set (1), this bit indicates that one of the reasons the *Validity* bit is set is that the object has lost communications with the device actually gathering the value of the point.

Forced - Indicates how the value was established. If set (1), this bit indicates that the reported value of this point is not necessarily the actual value. The point has been "forced" to report this value either locally, or via a write operation from the master. The *Validity* bit may be set or clear when *Forced* is set, since the forced value may or may not be valid.

Over Range - This is only applicable to *Analog Values*. If set (1), this bit indicates that the value is invalid because the value being measured has exceeded the physical capabilities of the hardware performing the measurement. This bit thus indicates that one of the reasons the *Validity* bit is set is that the value is over range.

Bad Reference - This is only applicable to *Analog Values*. If set (1), this bit indicates that the value is invalid because the reference value used to calibrate the *Analog Value* is incorrect.

Bit Number	Quality
0	Reserved
1	Invalid
2	Comm
3	Forced
4	Over Range
5	Bad Reference
6-15	Unassigned (future)

<u>ff</u>
Frozen floating point value.

<u>fi</u>
Frozen value of the “i” component.

<u>ft</u>
Frozen timestamp.

<u>r</u>
Summation value of the measurement

<u>CumDmd</u>
Integral value of demand over time. Value is resetable.

<u>ContCumDmd</u>
Non-resetable integral of demand over time.

<u>Pks</u>
Array of Pks structures with recent peak information.

<u>s</u>
Scale to be applied to integer value, i.

<u>o</u>
Offset to be applied to integer value , i, multiplied by scale, s, to arrive at scaled value.

<u>u</u>
see AI units of measure in previous section.

<u>uco</u>
Units of measure of coincident measurement. See AI units of measure in previous section.

<u>min</u>
Minimum value.

<u>max</u>
Maximum value.

<u>incr</u>
Increment by value can change.

<u>MxTyp</u>
Measurement Type, Identifies what the *Field Device Measurement* represents, i.e., the present value, peak, zero sequence component, etc. over the number of samples. The bits representing *Measurement Type* are:

Integer Value	Measurement Type
1	Present Value
2	Maximum Value
3	Minimum Value
4	Peak
5	Zero Sequence
6	Positive Sequence
7	Negative Sequence

MxRef
Measurement Reference, Describes the phase measurement, if any, associated with the *SIUnits*, i.e., phase 1, phase 1 to phase 2, 3 phase, etc., and the location of the measurement, i.e., source side, load side, etc. The integer representations of *Measurement Reference* are:

Integer Value	*Measurement Reference*
1	Unknown
2	Phase 1
3	Phase 2
4	Phase 3
5	Neutral
6	Phase 1 To Phase 2
7	Phase 2 To Phase 3
8	Phase 3 To Phase 1
9	Phase 1 To Neutral
10	Phase 2 To Neutral
11	Phase 3 To Neutral
12	Neutral To Ground
13	3 Phase
14 -15	Unassigned (future use)

MxLoc
Location reference of measurement.

SmpRat
Sample rate.

NumSmp
Number Samples, If applicable, this is the number of samples used in the actual measurement associated with the *Measurement Type*.

TimBas
Timebase of measurement. See TimBas above.

QuadAcct
Describes quadrant of accountability for measurement.

0	Quadrant 1
1	Quadrant 2
2	Quadrant 3
3	Quadrant 4

NetFlow
This bit is required to identify the manner in which the quadrants specified are being summed.

FALSE Absolute power delivered through selected quadrants, *i.e.,* power is added positively regardless of direction of flow.

TRUE Net of delivered - received, where Watts are delivered in quadrants Q1 & Q4, received in quadrants Q2 & Q3; and VARs are delivered in quadrants Q1 & Q2, received in quadrants Q3 & Q4.

HarComp
This identifies harmonic related quantities.

0 This is the entire signal un-filtered.
1 This is a harmonic component of an associated source.

NumDms
Number of demands in the peaks array.

pp
PsuedoPoint, flag that when set, indicates the value is substituted. For example, a measurement that is not currently being updated from an AtoD converter and has its value "stuffed."

db
Deadband.

hl
High limit.

ll
Low limit

hhl
High high limit.

lll
Low low limit.

d
Description of the component.

11.2.9 LPTable

Component Name	CLASS	FC	Description [ANSI C12 TABLE:ID]
LPTable	STRUCT		Load profile measurement data
|__MaxFlgs	LPFlgs	DC	60:LP_FLAGS
|__MaxNumBlks	INT16U	DC	60:NBR_BLKS_SETX
|__MaxNumBlkIntvl	INT16U	DC	60:NBR_BLK_INTS_SETX
|__MaxNumChan	INT8U	DC	60:NBR_CHNS_SETX
|__MaxMaxIntvlTim	INT8U	DC	60:MAX_INT_TIME_SETX
|__Flgs	LPFlgs	CF	61:LP_FLAGS
|__NumBlks	INT16U	CF	61:NBR_BLKS_SETX
|__NumBlkIntvl	INT16U	CF	61:NBR_BLK_INTS_SETX
|__NumChan	INT8U	CF	61:NBR_CHNS_SETX
|__MaxIntvlTim	INT8U	CF	61:MAX_INT_TIME_SETX
|__Chans	STRUCT	CF	62:LP_SOURCE_SEL_RCD
| |__Src	UINT8	CF	62:INTERVAL_SOURCE
| |__EndSrc	UINT8	CF	62:END_READING_SOURCE
| |__Sclr	UINT16	CF	62:SCALAR
| |__Dvsr	UINT16	CF	62:DIVISOR
|__t	t	MX	64:BLK_END_TIME
|__q	BSTR8	MX	64:EXTENDED_STATUS

Component Name	CLASS	FC	Description [ANSI C12 TABLE:ID]
|__End	INT16S[]	MX	64:END_READING
|__acc	INT32S	MX	64:END_ PULSE
|__IntvlQ	BOOL[][]	MX	64:SIMPLE_STATUS
|__IntvlStat	LPMXQ[][]	MX	64:EXTENDED_INT_STATUS
|__IntvlDat	INT16S[][]	MX	64:INTERVALS
|__Flgs	LPFlgs	ST	63:LP_SET_STATUS_FLAGS
|__NumValidBlk	INT16U	ST	63:NBR_VALID_BLOCKS
|__LstBlkElem	INT16U	ST	63:LAST_BLOCK_ELEMENT
|__NumValidIntvl	INT16U	ST	63:NBR_VALID_INT

LPTable
LPTable is a complete description of a load profile table.

MaxFlgs
See LPFlags, above.

MaxNumBlks
Maximum number of blocks supported in the device.

MaxNumBlkIntvl
Maximum intervals per block.

MaxNumChan
Maximum number of channels per block.

MaxMaxIntvlTim
The maximum time in minutes for load profile interval duration which can be contained in table.

Flgs
Actual current value LPFlgs bits.

NumBlks
Current number of blocks.

NumBlkIntvl
Current number of intervals per block.

NumChan
Current number of channels.

MaxIntvlTim
The maximum time in minutes for load profile interval duration which can be contained in table.

Chans
Channel definition of load profile in this table.

Src
Interval source.

EndSrc
End reading source.

Sclr
Scalar multiplier of counts in profile. This puts the counts in profile on the same basis as the integer component of the measurement.

Dvsr
Divisor of counts in profile.

t
Block end time. The timestamp of the last valid interval in the block.

q
Extended status bits of the table.

End
Array of end reading for each channel at last interval in block.

acc
The values of the accumulator at the end of a user defined interval.

IntvlQ
Simple status for each interval.

IntvlStat
Extended status for each interval.

IntvlDat
Interval measurements for each channel and interval.

Flgs
Status flags for entire set.

NumValidBlk
Number of valid blocks.

LstBlkElem
Last block element.

NumValidIntvl
Number of valid intervals.

11.3 ANSI C12.19 full meter model

This section summarizes the details of the full ANSI C12.19 meter model. Most components are broken out in complete detail down to a primitive type with the exception of the enumerations and bitstrings, and, the few structured components defined in the previous section.

Component Name	CLASS	FC	Description
Meter	STRUCT		Meter model
|__Extents	STRUCT		Description
| |__Cnf	ENUM8	DC	0:DEFAULT_SET_USED3
| |__SrcFlgs	MtrSrcFlgs	DC	10:SOURCE_FLAGS
| |__NumUOMEntry	INT8U	DC	10:NBR_UOM_ENTRIES
| |__NumDmdCtlEntry	INT8U	DC	10:NBR_DEMAND_CTRL_ENTRIE
| |__DatCtlLen	INT8U	DC	10:DATA_CTRL_LENGTH
| |__NumDatCtlEntry	INT8U	DC	10:NBR_DATA_CTRL_ENTRIES
| |__ConstSel	INT8U	DC	10:CONSTANTS_SELECTOR
| |__NumSrc	INT8U	DC	10:NBR_SOURCES
| |__RegFuncs	MtrRegFuncs	DC	20:REG_FUNC1_BFLD, REG_FUNC2_BFLD
| |__NumSlfRead	INT8U	DC	20:NBR_SELF_READS
| |__NumSumm	INT8U	DC	20:NBR_SUMMATIONS
| |__NumDmd	INT8U	DC	20:NBR_DEMANDS
| |__NumCoin	INT8U	DC	20:NBR_COIN_VALUES
| |__NumOcc	INT8U	DC	20:NBR_OCCUR
| |__NumTiers	INT8U	DC	20:NBR_TIERS
| |__NumPresDmd	INT8U	DC	20:NBR_PRESENT_DEMANDS
| |__NumPresVal	INT8U	DC	20:NBR_PRESENT_VALUES
|__Cfg	STRUCT		Meter configuration

| |__SrcFlgs	MtrSrcFlgs	CF	11:SOURCE_FLAGS
| |__NumUOMEntry	INT8U	CF	11:NBR_UOM_ENTRIES
| |__NumDmdCtlEntry	INT8U	CF	11:NBR_DEMAND_CTRL_ENTRIE
| |__DatCtlLen	INT8U	CF	11:DATA_CTRL_LENGTH
| |__NumDatCtlEntry	INT8U	CF	11:NBR_DATA_CTRL_ENTRIES
| |__ConstSel	INT8U	CF	11:CONSTANTS_SELECTOR
| |__NumSrc	INT8U	CF	11:NBR_SOURCES
| |__RegFuncs	MtrRegFuncs	CF	21:REG_FUNC1_BFLD, 21:REG_FUNC2_BFLD
| |__NumSlfRead	INT8U	CF	21:NBR_SELF_READS
| |__NumSumm	INT8U	CF	21:NBR_SUMMATIONS
| |__NumDmd	INT8U	CF	21:NBR_DEMANDS
| |__NumCoin	INT8U	CF	21:NBR_COIN_VALUES
| |__NumOcc	INT8U	CF	21:NBR_OCCUR
| |__NumTiers	INT8U	CF	21:NBR_TIERS
| |__NumPresDmd	INT8U	CF	21:NBR_PRESENT_DEMANDS
| |__NumPresVal	INT8U	CF	21:NBR_PRESENT_VALUES
| |__SummSel	IDENT[ ]	CF	22:SUMMATION_SELECT
| |__DmdSel	IDENT[ ]	CF	22:DEMAND_SELECT
| |__MinOrMaxFlgs	BSTRN	CF	22:MIN_OR_MAX_FLAGS
| |__CoinSel	IDENT[ ]	CF	22:COINCIDENT_SELECT
| |__CoinDmdAssoc	IDENT[ ]	CF	22:COIN_DEMAND_SELECT
|__Regs	RegDatRcrd		23:CURRENT_REGISTER_DATA_RCD
|__DmdCtrl			13:DEMAND_CONTROL_RCD
| |__RstExcl	INT8U	CF	13:RESET_EXCLUSION
| |__PFExcl	INT8U	CF	13:P_FAIL_EXCLUSION
| |__DetctTim	INT8U	CF	13:P_FAIL_RECOGNITION_TIM
| |__CldLoadPUTim	INT8U	CF	13:COLD_LOAD_PICKUP
| |__Intvls	STRUCT[]	CF	13:INTERVAL_VALUE
| |__Intv	INT16U	CF	13:INT_LENGTH
| |__SubInt	INT8U	CF	13:SUB_INT
| |__IntMlt	INT8U	CF	13:INT_MULTIPLIER
|__Status	STRUCT	ST	Status of IED
| |__Enable	BOOL	ST	3:METERING_FLAG
| |__TstMod	BOOL	ST	3:TEST_MODE_FLAG
| |__Factory	BOOL	ST	3:METER_SHOP_MODE_FLAG
| |__IEDStatus	IEDStat	ST	3:ED_STATUS_1
| |__MtrStatus	StFlgs	ST	Miscelaneous status flags
| |__NumPend	INT8U	ST	0:NBR_PENDING (deferred actions)
|__Cmds	STRUCT		Commands
| |__Enable	BOOL	CO	Control of enable
| |__LPEna	BOOL	CO	7,8:START LOAD PROFILE PROC
| |__TstMod	BOOL	CO	Enter test mode
| |__Factory	BOOL	CO	Reset to factory defaults
| |__ColdStart	BOOL	CO	7,8:COLD START PROC
| |__WarmStart	BOOL	CO	7,8:WARM START PROC
| |__SaveCfg	INT8U	CO	7,8:SAVE CONFIGURATION PROC
| |__ClrDat	BOOL	CO	7,8:CLEAR DATA PROC
| |__Status	BSTR16	CO	7,8:CLEAR STATUS FLAGS
| |__RmtRst	BSTR16	CO	7,8:REMOTE RESET
| |__SlfTst	BOOL	CO	7,8:EXECUTE DIAGNOSTICS PROC
| |__RestoreCfg	INT8U	CO	Restore configuration from saved
|__LPCfg	STRUCT		LoadProfile Subsystem configuration

| |__Len	INT32U	CF	61:LP_MEMORY_LEN
| |__Flgs	LPFlgs	CF	61:LP_FLAGS
|__LP1	LPTable	LG	64:LP_DATA_SET1_TBL
|__LP2	LPTable	LG	65:LP_DATA_SET2_TBL
|__LP3	LPTable	LG	66:LP_DATA_SET3_TBL
|__LP4	LPTable	LG	67:LP_DATA_SET4_TBL
|__PrevSeason	STRUCT	LG	24:PREVIOUS_SEASON_DATA_RCD
| |__Info	UtilSRMXInfo		24:REGISTER_INFO_RCD
| |__Data	RegDatRcrd		24:PREVIOUS_SEASON_REG_DATA
|__PrevDmdRst	STRUCT	LG	25:PREVIOUS_DEMAND_RESET_DATA_RCD
| |__Info	UtilSRMXInfo		25:REGISTER_INFO_RCD
| |__Data	RegDatRcrd		25:PREVIOUS_DEMAND_RESET_DATA
|__SRReg	MtrSRReg	LG	26:SELF_READ_LIST_RCD
|__Tables	INT8U[ ][ ]		Byte oriented “table” interface
|________________________…	UtilMX		Measurements will be added for each measurement present derived from UtilMX class

Meter
The ANSI C12.19 model of a generic revenue metering class device.

Extents
Maximum degrees of freedom for meter model.

Cnf
Meter conformance class. Identifies a reference for the entire configuration of this meter.

0	Conformance class 0
1	Conformance class 1
2	Conformance class 2
3	Conformance class 3
4..255	<Not yet defined>

SrcFlgs
See MtrSrcFlgs above.

NumUOMEntry
Number of C12.19 unit of measure entries.

NumDmdCtlEntry
Number of demand control entries.

DatCtlLen
Data control table length.

NumDatCtlEntry
Number of data control table entries.

ConstSel
Constants selections.

NumSrc
Number of measurement sources.

RegFuncs
See MtrRegFuncs above.

NumSlfRead
Number of self reads supported.

NumSumm
Number of summations.

NumDmd
Number of demands stored.

NumCoin
Number of coincident measurements supported.

NumOcc
Number of peak occurrences supported.

NumTiers
Number of tiers present.

NumPresDmd
Number of present demands stored.

NumPresVal
Number of present values stored.

Cfg
General configuration information about the meter.

SrcFlgs
See MtrSrcFlgs above.

NumUOMEntry
Number of C12.19 unit of measure entries.

NumDmdCtlEntry
Number of demand control entries.

DatCtlLen
Data control table length.

NumDatCtlEntry
Number of data control table entries.

ConstSel
Constants selections.

NumSrc
Number of measurement sources.

RegFuncs
See MtrRegFuncs above.

NumSlfRead
Number of self reads supported.

NumSumm
Number of summations.

NumDmd
Number of demands stored.

NumCoin
Number of coincident measurements supported.

NumOcc
Number of peak occurrences supported.

NumTiers
Number of tiers present.

NumPresDmd
Number of present demands stored.

NumPresVal
Number of present values stored.

SummSel
Array of summation selections. Identifies sources.

DmdSel
Array of demand measurement selections.

MinOrMaxFlgs
Array of flags to show if demand peaks are minimums or maximums.

CoinSel
Array of coincident measurement selections.

CoinDmdAssoc
Array of coincident demand associations.

Regs
Register data of the meter. See RegDatRcrd above.

DmdCtrl
Demand control and status information.

RstExcl
Number of minutes after demand reset to exclude additional reset action.

PFExcl
Number of minutes after a valid power failure occurs to inhibit demand calculations.

DetctTim
Number of seconds after a power failure occurs until a valid power failure is recorded and a specified action is initiated.

CldLoadPUTim
Number of minutes after a valid power failure occurs to provide cold load pickup functions.

Intvls
Structure describing the intervals of demand measurement.

Intv
Each of the entries in this array is associated to an entry in the SOURCES_TBL (Table 16). This array contains one entry for each SOURCES_TBL (Table 16) entry having the DEMAND_CTRL_FLAG set. The order of the parameters in this array corresponds to the order of the sources in table SOURCES_TBL (Table 16).

SubInt
The number of minutes in the subinterval.

IntMlt
The multiplier by which the SubInt is multiplied. (Note that SubInt and IntMlt ensures even minute boundaries for intervals and simplifies synchronization with hour change and new day changes).

Status
General status information about the meter.

Enable
Enable recording in the meter.

TstMod
Meter is in test mode.

Factory
Meter is in factory calibration mode.

IEDStatus
Status of various fault condition flags in meter.

MtrStatus
Additional meter status flags.

NumPend
Number of pending self reads.

Cmds
Commands to change the mode of operation of the meter.

Enable
Set the enabled status of the meter.

LPEna
Enable/disable load profiling.

TstMod
Enter/leave test mode.

Factory
Enter/leave factory test mode.

ColdStart
Perform a cold start.

WarmStart
Perform a warm start.

SaveCfg
Save the configuration.

ClrDat
Clear data registers.

Status
Clear selected status flags.

RmtRst
Remote restart of meter process.

SlfTst
Perform self test.

RestoreCfg
Restore saved configuration.

LPCfg
Load profile recording subsystem configuration.

Len
Total length in bytes of load profile storage.

Flgs
Status flags for load profile subsystem.

LP1
Load profile table 1.

LP2
Load profile table 2.

LP3
Load profile table 3.

LP4
Load profile table 4.

PrevSeason
Snapshot of register information from previous season.

Info
See UtilSRMXInfo, above.

Data
Snapshot of meter’s register data record.

PrevDmdRst
Snapshot of register contents at last demand reset.

Info
See UtilSRMXInfo, above.

Data
Snapshot of meter’s register data record upon previous demand reset.

SRReg
Self read register log.

Tables
The meter viewed as a set of “tables” organized as arrays of bytes. This view presents a purely C12.19 view of the meter without object oriented access of individual components by name.